ESTIMATION OF ANTHROPOGENIC CO AND NO_X EMISSIONS FOR KANPUR CITY

A Thesis Submitted
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

by

Capt Deepak Sharan

to the

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
MARCH, 1996

Dedicated

to

My parents

CERTIFICATE

It is certified that the work contained in the thesis entitled, **"Estimation of Anthropogenic CO and NO_x Emissions for Kanpur City"**, has been carried out by **Capt. Deepak Sharan** under my supervision.

Vinod Tare
Associate Professor
Department of Civil Engineering
Indian Institute of Technology
KANPUR

March 1996

ACKNOWLEDGEMENTS

The duty of noble heart is the acknowledgement of the gratitude. I feel indebted to my guide, Dr. Vinod Tare, Associate Professor, IIT, Kanpur who was the sole prop in my venture of completing this dissertation. The discussions that we had during the course of the study made me more conversant with the subject and his being a very cheerful source of inspiration throughout took me all the way through the project.

I am grateful to Dr. D.K. Ghosh for providing me with relevant literature for thesis. Thanks are due to Dr. Malay Chaudhuri and Dr. C. Venkobachar who have been very helpful throughout the period of my dissertation. I owe them my sincere thanks.

My thanks are also due to my seniors for their kind patronage and valuable suggestions. The encouragement and Support of my family, colleagues and well wishers is much appreciated.

At last but not the least I would like to thank those of my friends who served to revive my enthusiasm and put back into the main stream of work.

Indian Institute of Technology
Kanpur

Capt. Deepak Sharan

CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In the present work, study is being undertaken to estimate the anthropogenic CO and NO_x emissions for Kanpur city. This study is carried out to identify all the anthropogenic activities which cause CO and NO_x emissions and estimate such emissions in Kanpur city. The activities include all types of transport, viz. two wheeler vehicle (TWV), light transport vehicle (LTV), heavy transport vehicle (HTV), consumption of all types of domestic fuels and industrial activities. Emissions due to transport activities are estimated for all the major road network in Kanpur city. Emissions due to the activity of consumption of domestic fuels are estimated for all the wards of Kanpur city. Emissions are measured for peak and average conditions. Industrial activity includes all those industries of Kanpur which cause CO and NO_x emissions. The emission inventory has been developed to serve as a vital input for assessing the air quality in Kanpur city. The knowledge of emission inventory can be applied to the shaping of public policy in the intereest of safeguarding the environment.

1. INTRODUCTION

It is the first basic right of every living organism to breath the fresh air, e.g. the air free from any gaseous pollutant or suspended particulate matter, the air which does not cause any health hazard, etc. One of the biggest problem that confronts mankind today is that of air quality degradation caused by the waste remaining from the ways the human beings produce goods, transport themselves and generate the energy to heat and light for mankind requirement. It is important to asses the air quality with a view to finding out the extent of air quality degradation and to take suitable measures in future to make a healthy and friendly environment.

One of the approaches to asses air quality is to measure pollutant levels through installation of general monitoring stations. This approach gives reasonably good estimate of air quality parameters in the vicinity of the monitoring station at the time of recording. However, installation of several monitoring stations which can automatically record various parameters is very expensive and unaffordable in most of the places, particularly in developing world. Another major limitation with this method is that the pollutants concentration at any particular place and time change considerably and at times may not represent the normal levels. For example, if at a place, some excess emissions take place at a particular time due to accident then air quality monitored at that time misrepresents normal air quality in that locality.

The other approach to assess the air quality is to relate pollutant levels to their sources. This approach is less resource intensive and can lead to reasonably good estimate of average air quality in a given geographical area. One of the important requirements in adopting this approach for air quality estimates is to quantify emissions of various pollutants. In the present thesis an attempt is made to formulate a procedure for preparing emission inventory in an urban area and to apply this procedure for preparing CO and NO_x emission inventory due to anthropogenic activities in Kanpur city.

2. LITERATURE REVIEW

2.1 GENERAL

Air pollution is woven throughout the fabric of our modern life. A byproduct of the manner in which cities are built up. Air pollution may result from either man-made processes or natural processes such as forest fires, decaying of vegetation, dust storms, volcanic eruptions, etc. which always contaminate the air. Although the total global production of many gases and particulate matter recognised as pollutants is much greater from natural sources than from man-made sources. Global distribution and dispersion of those pollutants result in low average concentrations. By precipitation, oxidation and absorption into the oceans and the soil, the atmosphere can change itself of all known pollutants given sufficient time [1].

2.2 AIR POLLUTION

Air pollution due to anthropogenic i.e. man-made processes results from residues/wastes remaining from the ways the goods are produced, men and goods are transported and energy is generated to heat and light the places of work where mankind activities take place. The major cause of air pollution due to man-made is combustion and combustion is essential to man. When perfect or theoretical combustion occurs, the hydrogen and carbon in the fuel combine with oxygen from the air to produce heat, light, carbon dioxide and water vapor. However, impurities in the fuel, poor fuel to air ratio, or too high or too low combustion temperatures

cause the formation of such side products as carbon monoxide, sulfur oxides, nitrogen oxides, fly ash, and unburnt hydrocarbons — all air pollutants. Man-generated pollutants are usually concentrated in small geographic regions, hence most air pollution is truly man-made. Currently the rate at which pollutants are discharged into the atmosphere in highly populated regions at time exceeds the cleansing rate of the atmosphere.

Man-made activities such as quantity of goods and services is closely related to the quantity of energy consumed (directly or indirectly) by that activity. In other words, the availability and use of energy is a requisite for a high standard of living. An increase in demand per capita in the developing countries, similar to that experienced in West Germany and the USA, in combination with the increase in global population can result in uncontrolled emissions of air pollutants in catastrophic proportions.

2.3 ROLE OF EMISSION INVENTORY

In the past, industry, agriculture, and individual polluters have found it more economical to discharge waste products into the atmosphere than to exercise waste control. In general the organisation or activity causing the pollution does not suffer the consequences of the pollution. Likewise, those who benefit from a reduction in air pollution resulting from the installation of control equipment do not directly bear the cost of the equipment. In recent years, as the public has become increasingly concerned with environmental problems, air has to be regarded as a resource

within the public domain. Hence, air pollution is considered a public problem, a concern not only of those who discharge the pollution, but also of those who may suffer as a result. Hence, it is a first basic requirement to have an emission inventory for a geographic location where a lot of man-made activities take place. This emission inventory becomes the first basic input to be applied in any air pollution model to estimate the air pollutant concentration at any place and at any time. The knowledge of emission inventory can be applied to the shaping of public policy in the interest of safeguarding the environment.

Activities which result in anthropogenic air emissions can be classified in three broad groups. First is line source taking care of all types of transport e.g. TWV (two wheeler vehicle), LTV (light transport vehicle) and HTV (heavy transport vehicle). Second one is area source which takes care of all domestic fuels. Third one is point source taking care of all industrial emissions. This classification is justified with the type of emissions confined to a city.

2.4 MEASUREMENT OF EMISSIONS

An accurate calculation of the rate of emission of a pollutant at a given location and time requires collection and analysis of a comprehensive data based on numerous variables including the following:

(a) Source categories

(b) Type of fuel used

(c) Fuel quantity used by each emission source

(d) Pollutant content of fuel for each category

(e) Development of emission factors.

After these variables are either measured or estimated for a particular time and location, the information is combined to calculate emissions. In practice, emissions are obtained as aggregates for an area such as a grid cell, city, county or country. In making area estimates, emission factors, of necessity, have to be averaged over all operating sources with in a particular category for the same year. In foreign countries, a number of works have been done to estimate emissions and to accurately measure the variables. Some of which are described here.

2.5 EMISSION FACTORS DEVELOPED ABROAD

In developed countries like USA, Australia and UK a number of research studies are reported and they provide the vehicular emission factors for hot and cold start conditions for the vehicles of their countries [2]. World Health Organizations (WHO Pub. No. 6) has also published vehicular emission factors.

The determination of accurate in-use vehicle emission factors is critical in the evaluation of the effect of vehicle emission control on air quality. EPA's emission factor program [3] is instituted to provide emission estimates for in-use vehicles for various urban scenarios. These are documented in the EPA publications Mobile1 [4] and the more recent Mobile2 [8]. The emission rates in these documents are suggested by EPA for use in modeling CO air quality. For the most part EPA's method for

determining mobile source emission factors is based on the Federal Test Procedure (FTP) which includes a composite of various driving modes [2, 3, 4, 6, 11]. The emission factors are usually obtained from dynamometer measurements with little or no roadside measurements included. To study vehicular emissions under actual but still well-defined conditions, aerometric measurements have been made for a number of years at the Allegheny Mountain and Tuscarora Mountain Tunnels on the Pennsylvania Turnpike [5]. CO emission rates for gasoline vehicles (predominantly light duty) and for heavy duty diesel vehicles obtained from tunnel experiments during the summer of 1979 are presented below:

CO emission rates obtained for gasoline and diesel vehicles from 1979 Allegheny Tunnel experiments

	Measuring location		
	Left lane	Right lane	average
May 1979			
Number of hourly measurements	131		
Correlation coefficient	0.95		
Emission rate (g/km)			
Gasoline powered vehicle	8.5 ± 0.3	(12.2)[a]	10.4 ± 2.6
Diesel powered vehicle	4.7 ± 1.8	(5.5)[a]	5.1 ± 0.6

a : estimated from left-right ratio.

A comparison of CO emission factors derived from Allegheny and Mobile 1 and Mobile 2 is given below:

	Allegheny	Mobile 1[a]	Mobile 2[a]
Gasoline vehicles (g/km)	10.4 ± 2.6[b]	12.4	15.4
Diesel vehicles (g/km)	5.6 ± 2.16	7.8	4.0

a : Calculated using vehicle average speed 80 km/h with vehicles in a hot stabilized mode.

b : Error estimated by averaging largest standard deviation of individual regressions.

2.6 EMISSIONS BY CATALYST EQUIPPED VEHICLES

A report published in USA [6] suggests that urban centre CO air quality after 1974 would improve faster than predictions based on current FTP emission factors because of the introduction of catalyst equipped light diesel vehicles. This conclusion is based on an analysis made with a generalized roll back model [3] which show that Federal Test Procedure (FTP) overestimates the contribution of cold start emissions to urban centre CO air quality (8-hr average). The overestimate is calculated to be small for noncatalyst equipped cars, but to become quite significant for catalyst equipped cars. The reason for the distinction for the catalyst equipped cars is that once the catalyst is lit off (warmed up), it removes virtually all of the CO (if sufficient oxygen is present). Therefore, for these cars

virtually all of the CO emissions in the Federal Test Procedure (FTP) occur during the cold start, before the catalyst is warmed up. Since most of the centre-city driving takes place with warmed-up catalysts, the effective CO emissions for catalyst equipped vehicles are significantly less than the CO emissions measured by the present Federal Test Procedure. Catalyst equipped cars are first introduced in the 1975 model year and the large disparity between the EPA emission factors and the CO air quality trends are seen.

2.7 EMISSIONS CAUSED BY FOSSIL FUEL COMBUSTION

Statistical model is developed [7] that relates the rate of emissions of a pollutant to the rate of fuel consumption. These are also used to estimate emissions in other regions, or at other times, if fuel consumption data are available. This approach is used to estimate global emissions of NO_x in fossil fuel combustion at ten year intervals from 1860 to 1980. Emissions from each of the populated continents, i.e. North America, South America, Asia, Europe, Africa and Oceania from 1930 to 1980 are also presented. When averaged globally over the 1860 to 1980 period, the nitrogen emissions increased at the rate of 3.4 percent per year. After the Second World War, the most rapid increases in emissions are registered in Asia, South America, and Africa.

In the United States, annual pollutant emissions have been compiled by the EPA and one of its predecessors the Public Health Service, on a State-by-State basis since 1966 and for some years during the period 1940-1965 [12-19]. Other industrialised

countries, notably members of the organisation of Economic Cooperation and Development (OECD), have also published estimates of emissions in the 1970's and 1980's. Because of absence of information on most of the variables, this method is not being applied to estimate pollutant emissions in less developed countries. Similarly, for the industrialized countries, lack of data for earlier years hinders the compilation of historical emission estimates. For this reason, a statistical model is developed [7] that allows to estimate emissions where very little is known about fuel type, source category, and emission factors. This method uses existing emission values from regions where emissions are known to parameterize and calculates emissions for countries and times when only the annual fuel consumption is known. The resulting emission models are obtained (1) by regression analyses performed on existing EPA emission trends data for the United States between 1940 and 1969; and (2) from emission estimates of Western Europe and other OECD member countries.

This method allows emissions to be expressed solely as a function of the fuel consumed. This is achieved by parameterizing emission estimates in terms of fuel consumption for countries where such estimates have been published using fuel consumption data which is readily available on a country by country basis, this model attempts to allow for differences between national environmental policies. This is done by performing separate regressions for nations with different pollution controls, i.e. by dividing the world into three emission regions:

1. United States
2. OECD member countries other than the U.S. (Australia, Canada, Japan)
3. Rest of the world.

These divisions only apply to the post 1970 period when significant emission controls were first imposed in Regions I and II. Prior to 1970, any controls which may have existed in these countries were geographically sparse and were sporadically implemented. So during the period prior to 1969 Regions I, II and III are considered together.

To estimate the amount of emissions in areas that have had on emission controls, there is a requirement to have a sample of emission estimates which also have no imposed regulations. It is assumed that the data available for the United States prior to 1970 is representative of a country with uncontrolled emissions. Curvilinear regressions are performed on United States emission estimates prior to 1970 that yield linear relationships for NO_x.

$$N = 0.0095 F$$

where N represents emissions of NO_x expressed in million metric tons (MMT) of equivalent NO_2 per year. F is the total fossil fuel consumption which includes the sum of the solid, liquid and gaseous fuels consumed in million tons of coal equivalent for a given year. The regressions have correlation coefficients of 0.98 and 0.99 respectively, the statistical significance of both being better than 98 percent.

This correlation is for non-control environments and different correlations are likely to apply for different control conditions. These regressions are used to model uncontrolled emissions i.e. emissions in Region III, in Region II prior to 1970 for those years where there are no official published estimates.

As mentioned earlier, OECD has published emission estimates for many of its member countries for the post 1970 period. Since, the coverage is not complete in the sense that estimates are not available for all countries on an annual basis. Hence additional regressions are carried out using the available post-1970 data from these countries. The following linear expression is obtained for Region II for the post 1970 period.

$$N = 0.0060\ F$$

where N represents emissions of NO_x expressed in million metric tons (MMT) of equivalent NO_2 per year and F is the total fossil fuel consumption in million tons of coal equivalent for a given year.

These relations are used to estimate OECD emissions for those countries and years in the post-1970 period for which official estimates are not available. These equations represent emissions from fossil fuel combustion only utilising the available fuel consumption data, emission estimates for each country are calculated for each year of the study and added to the continental total. Central America, Greenland and the Caribbean are considered to be part of North America. Asia includes all of the

USSR. Prior to 1925, regional estimates are not possible because fuel consumption data for individual nations are unavailable.

2.8 METHODOLOGY DEVELOPED BY FOREIGN COUNTRIES FOR PREPARING EMISSION INVENTORY BY CONDUCTING EXPERIMENTS

A project work is being done by the California Air Resources Board, California to prepare the air emission inventory for the California city [8, 9, 10]. The work includes the following:

(i) A summer and a fall measurement program, consisting of both ground level and upper level air quality;

(ii) A quality assurance program;

(iii) An assessment of the emissions inventory and enhanced efforts during the study period;

(iv) Emissions characterization studies.

The work consists of a series of experiments to monitor the air emissions and then develop the air emissions inventory based on the experimental results. The work consists of 11 intensive sampling days in the summer and six intensive sampling days in the fall, with five sampling periods per day. During the summer, two sampling locations are heavily instrumented with numerous research projects and aircraft measurements. The monitoring is done for 24 h and for three months continuously and emissions inventory are prepared based on the results.

2.9 WORK DONE IN INDIA FOR PREPARING EMISSION INVENTORY

Such works have been completed before by the Central Pollution Control Board and the reports have been published by the CPCB [20, 21-26].

Methodology developed by Central Pollution Control Board in the above projects: Central Pollution Control Board adopts the following methods to prepare the emission inventory for a city.

2.10 METHODOLOGY FOR LINE SOURCE ADOPTED BY CPCB

It computes the line source emissions based on the distance, traversed by the vehicles. It carries out the door to door survey to find out the distance traversed by each vehicle, in a day. It collects the home addresses of all the vehicle owners and carries out the survey. Emissions are computed based on the distance traversed by a vehicle on a particular stretch of road at a particular time.

The biggest drawback with this methodology lies with the attitude of the vehicle owner. If the vehicle owner changes the route, time of travel or the mode of transport then the methodology adopted this way does not produce fair results.

2.11 METHODOLOGY FOR AREA SOURCE ADOPTED BY CPCB

It collects the data for all the domestic fuels, about its quantitative distribution, in different localities, on a daily basis, from the main supply agencies e.g. Indian Oil Corporation, Forest Department, State Supply Department

The data for various domestic fuels are collected from the following agencies:

(i) LPG - Indian Oil Corporation, Hindustan Petroleum

(ii) Kerosene oil - Supply Department

(iii) Wood - Forest Department

(iv) Coal - Supply Department

(v) Cowdung - From survey data only.

After knowing the average quantities used daily in a locality for different domestic fuels, the area source emissions are computed simply by multiplying the quantity of domestic fuel with the emission factor of that fuel. The biggest drawback with this methodology lies with the attitude of the users. Users may not consume the same quantity of domestic fuels what is actually purchased by them. Users may save some quantities of domestic fuels as a buffer stock. Hence, methodology adopted this way does not give fair results.

2.12 METHODOLOGY FOR POINT SOURCE ADOPTED BY CPCB

Data is collected about the quantitative use of various industrial fuels by the industries, its average and peak consumption rates, and the process emissions caused by the industries if any. Point source emissions are computed by simply multiplying the quantity of industrial fuel with the emeission factor of that fuel. Process emissions (if any caused by the industry) are also added to give the total emission rate due to point source.

3. OBJECTIVE AND SCOPE

A brief review of the literature presented in previous section reveals that the literature on estimating air pollution levels related to the anthropogenic emission sources is very insignificant in the context of Indian urban centres. This is due to the lack of information on emission sources and rates. The proper methodology for carrying out emission inventories due to anthropogenic activities to suit Indian cities is not reported. Also, very few studies have been undertaken to estimate emission of pollutant loads due to various anthropogenic activities. As such the objectives of the present thesis is (1) to formulate a suitable methodology to carry out air pollutant emission inventories, which will ultimately serve as a useful input in predicting air quality, for various major anthropogenic activities to suit Indian cities, and (2) to illustrate application of the formulated methodology for making inventory of CO and NO_x emissions in Kanpur city. The work is done on following lines.

1. Identification of various types of anthropogenic activities which result in significant contribution of air pollutants under study.
2. Ascertaining/quantifying the level alongwith aerial distribution of activities identified as in 1 above.
3. Correlating the pollutant emission with level of activity.
4. Illustrating application of the methodology developed through steps 1 to 3 above for estimating CO and NO_x emissions in Kanpur city.

3.1 GENERAL METHODOLOGY

A general methodology has been developed to prepare emission inventory for any urban city.

3.1.1 Line Source Emissions

3.1.1.1 Factors affecting the emissions due to line source

Following are the factors which affect the emissions caused by the activities of the transport vehicles, generally referred as line source emissions.

(i) Change in the vehicle speed:

Emissions caused during acceleration and deacceleration of a vehicle is 10 times more than the emissions caused at the idling speed of a vehicle.

(ii) Inspection/maintenance programmes of the vehicles.

(iii) Ambient temperature.

(iv) Tampering with the emission control system on automobiles.

(v) Air conditioning usage.

(vi) Percentage of Vehicles in the hot/cold start mode.

(vii) Loading of the vehicle.

3.1.1.2 Steps to compute emissions due to line source

(i) First information required for the computation of emissions is about the traffic volumes (veh/h) for TWV, LTV and HTV during peak and average traffic conditions. To achieve this task a traffic survey is conducted on all the road network, in the city, for 24 hours at least, to find the peak and average traffic volume for TWV, LTV and HTV. If PCU (passenger car unit) is available for all the road

network from traffic engineers then traffic volumes for TWV, LTV and HTV are obtained from PCU. Method to convert PCU into traffic volumes for TWV, LTV and HTV is discussed in Chapter 4.

(ii) Speed of a vehicle (in kmph) is being computed for TWV, LTV and HTV from the traffic volumes by using speed traffic flow equations. These equations are given in Table 3. These equations are developed by IRC (Indian Road Congress, Delhi) and can be applied on an urban Indian city.

(iii) After computing speed for the TWV, LTV and HTV, the emission factors (in kg/km) are computed. These emission factors are computed for all the vehicle category by using the speed-emission factor equations given in Table 4. These equations are developed by the Indian Institute of Petroleum, Dehradun. These equations can be applied for TWV, LTV and HTV of Indian origin for any city in India.

(iv) After computing emission factor, the emission rate (in kg/h) is being computed for the TWV, LTV and HTV by the following formulae:

Emission rate (kg/h) of a vehicle type	=	Traffic volume of that vehicle type (veh/h)	*	Emission factor of that vehicle type (kg/km/veh)

Finally, all the emission rates due to TWV, LTV and HTV are summed up to give the total emission rate due to all vehicle types on a road.

3.1.1.3 Emission factor and its estimation

Emission Factor:

Emission factor for a line source is defined as the amount of gaseous pollutant released by a vehicle after one km run at a particular speed. Its unit is kg/km/veh.

Estimation of Emission Factor:

Emission factor is being estimated by the Indian Institute of Petroleum by measuring the gaseous pollutant released by the vehicle after one km run at a particular speed and under standard operating conditions.

3.1.1.4 Assumptions for line source emission

Following assumptions are made while preparing emission inventory due to line source:

(i) Traffic volume remains same throughout the length of the road.

(ii) Vehicles ply with the uniform speed on a particular stretch of road.

(iii) Peak traffic period continues for two hours in the morning and for two hours in the afternoon. Peak traffic period continues for three hours in the evening.

(iv) Emission factor remains same for different types of vehicles in a particular vehicle category e.g. emission factor is constant for different types of two wheeler vehicles.

3.1.2 Area Source Emissions

It is caused by the activities of the burning of domestic fuels under this category following types of domestic fuels come:

LPG (liquid pressure gas)

Kerosene oil

Wood

Coal

Cow dung

Except LPG rest of the domestic fuels are used by the LIG people only. When small sources of emissions are collectively considered as one source and over the entire area of small sources taken into account then it is considered as area source e.g. LPG cylinders when burning in large quantity over an area constitutes area source of emission.

Following are the factors which affect the area source emissions:

(i) Quantity of domestic fuel being consumed

(ii) Type of heating

(iii) Population distribution

(iv) Socio-economic status of the people

(v) Duration of combustion

(vi) Ventilation of kitchen

(vii) Emission factor of the domestic fuel.

3.1.2.1 Steps to compute emission rate due to area source

(i) First data required for the computation of emission rate

due to area source is about the population distribution of a city area wise and income group wise. Once, the data is obtained area/ward wise and based on HIG, MIG and LIG then number of fuel units are computed. Usually five persons constitute one fuel unit. This is verified also by conducting socio-economic survey.

(ii) A socio-economic survey is conducted ward wise to find out the following details:

(a) Percentage users of different types of domestic fuel among low income group people.

(b) Estimated average daily domestic fuel consumption rates among low income group for different types of fuels and among HIG and MIG.

(c) Number of persons in a household using a fuel unit.

(d) Number of hours, a fuel unit is being used.

After knowing the above details, the number of fuel units are computed for all types of fuels. HIG and MIG people contribute only for LPG fuel units. After knowing the number of persons in a household, the fuel units are computed simply by dividing the population in a ward with the number of persons staying in a house.

This gives the total number of fuel units in a ward. Since, percentage users of different types of domestic fuel among low income group people is known from the survey data, hence, number of fuel units of different fuel types among LIG is also computed by multiplying the total number

of fuel units with the fraction users of different types of domestic fuel, among LIG. Finally, all types of fuel units in a ward contributed by HIG, MIG and LIG are known.

(iii) Quantity used daily, of different fuel types is computed by multiplying the number of fuel units, of different types, with the corresponding average daily domestic fuel consumption rates. This gives the total quantity used, of different fuel types, in a day, ward wise. If this quantity is divided by 24 then average quantity, used per hour, of different fuel types, is obtained. Since, from the survey data, the number of hours a fuel unit is being consumed is known, hence, by dividing the quantity, used daily of different fuel types, with the number of hours, of the corresponding fuel unit being used, the quantity used during peak hour is obtained for different fuel types.

(iv) Finally the emission rates, ward wise is obtained by multiplying the fuel consumption rates (as computed above for different fuel types and for peak and average condition) with the emission factor. The emission rate is computed by the following formulae:

Emission rate (kg/h) of a fuel type	=	Fuel consumption rate (kg/h) of that fuel type	* Emission Factor of that fuel type (kg/kg)

The total emission rate in a ward due to all types of fuels is computed by summing up all the emission rates due to all types of fuels.

3.1.2.2 Emission factor and its estimation

Emission Factor: Emission factor of a fuel is defined as the amount of gaseous pollutant by weight released by burning the unit weight of that fuel under standard operating conditions e.g. at standard temperature, standard air/fuel ratio and standard composition of the fuel.

Estimation of Emission Factor: Emission factor of a fuel used either for domestic purpose or industrial purpose is determined by studying a combustion process on a typical standard combustion system adopted in a domestic household or in an industry and by carrying out mass balance study. It is determined at following standard operating conditions:

(i) Standard temperature of reactor

(ii) Standard air/fuel ratio

(iii) Uniform extent of combustion e.g. ideal combustion efficiency

(iv) Uniform characteristics of combustion fuel.

3.1.2.3 Assumptions for area source emission

Following assumptions are made while preparing emission inventory due to area source:

(i) In a household, kitchen is properly ventilated.

(ii) Estimated average domestic fuel consumption rates remain constant for a particular ward as obtained from the socio-economic survey data.

(iii) Composition of the domestic fuel of all types remain unchanged.

3.1.3 Point Source Emissions

It is caused by the activities of the industries. When at a particular point, a large amount of gaseous pollutant is being released then it is considered as a point source emission. Under this category various types of emissions come

(i) Industrial emissions

These emissions are of the two types.

(a) Process emissions: These are the emissions caused by the industry due to its process cycle used. These emissions are the product or byproduct of the industries.

(b) Emissions due to the burning of fuels by the industry. Industry generally use one of the following items as a fuel:

* Coal
* Low diesel oil (LDO)
* Diesel
* Wood.

(ii) Individual causing emissions: These are the emissions caused by the individuals for personnel purpose e.g. a person burning a huge quantity of residual crops. It is difficult to identify and measure such emissions.

(iii) Accidental emissions: These are the emissions caused by the accidents e.g. like bursting of a gas cylinder. These emissions cannot be predicted and can be measured only in the event of an eventuality.

3.1.3.1 Factors affecting point source emissions

Following are the factors which affect the point source emissions:

(i) Quantity of fuel and the type of fuel being used.

(ii) Composition of the fuel.

(iii) Type of combustion.

(iv) Type of process cycle.

(v) Emission factor of the fuel.

(vi) Duration of combustion of fuel

(vii) Control measures taken by the industry.

3.1.3.2 Steps to compute emissions area wise due to point sources

(i) Area wise data is collected for peak and average daily fuel consumption rates of various fuel types by the industries.

(ii) Area wise average and peak daily fuel consumption rates are computed for all the industries together and for all the fuel types. From the fuel consumption rates, the emissions are computed due to all fuel types. These emissions are summed up to give the total emission rate area wise for peak and average conditions. The emission rate is computed by the following formulae:

Emission rate of a fuel type (kg/h) = Fuel consumption rate of that fuel type (kg/h) * Emission factor of that fuel type (kg/kg)

3.1.3.3 Assumptions for point source emission

Following assumptions are made while preparing emission inventory due to the point source:

(i) Composition of the industrial fuel of all types remain unchanged.

(ii) Estimated average industrial fuel consumption rates remain constant for a particular industry.

3.1.4 Use of Speed-Volume Equations and Its Limitation

Speed-volume equations as given in Table 3 are developed by IRC, Delhi after carrying out traffic survey for urban cities. Traffic volumes and speed of different types of vehicles were found for many cities. Regression analysis was carried out to develop speed-traffic volume equations for different types of vehicles. These equations can be used for any urban city situated on the plain terrain and are applicable for all Indian origin vehicles. Major limitation of this equation is that it is not applicable for the new generation cars which have started plying on Indian roads after 1980.

3.1.5 Use of Speed-Emission Factor Equations and Its Limitation

Speed-emission factor equations have been developed by I.I.P. Dehradun after carrying out series of emission measurements of all types of vehicles at different speeds. Regression analysis was carried out to develop mathematical relations between emissions and speed of vehicle. Major limitation of this equation is that it is not applicable to imported cars though it can be used for all Indian cars which have been introduced up to 1990.

4. METHODOLOGY

4.1 GENERAL

The methodology as discussed in Chapter 3 is being used to compute emissions for CO and NO_x for Kanpur city due to the line source, area source and point source. Keeping in view the limitations of this M.Tech. thesis, suitable assumptions and changes are also incorporated wherever found necessary. Assumptions made in Chapter 3 are also valid here for the line source, area source and point source emissions. The methodology is being explained with the help of flow charts and the steps required to compute emissions.

4.2 FLOW CHART FOR COMPUTATION OF EMISSION RATE DUE TO LINE SOURCE

Collection of PCU/traffic volume (vehs/h) on road network from Traffic survey (Table 1)

↓

Conversion of PCU into traffic volume (vehs/h) for different vehicle types e.g. HTV, TWV and LTV (Table 1)

↓

Collection of data for increase in vehicle number of different types over last five years. Projection of the increase in vehicle number of different types against year on graph (Fig. 1)

↓

Finding the type of increase and equations showing relationship between increase in vehicle and year. Finding the multiplication factor for HTV, TWV and LTV (Table 2)

↓

Computation of traffic volumes for HTV, TWV and LTV for the predicted year, using above multiplication factors and total traffic volumes

↓

Computation of speed (kmph) for the HTV, TWV and LTV from the total traffic volume using speed-traffic volume equations (Table 3)

↓

Computation of emission factors (kg/km) from the speed for the TWV, LTV and HTV using speed-emission factor equations (Table 4)

↓

Computation of emission rate (kg/h) from the traffic volume and the emission factor for the TWV, LTV and HTV. Summing up all the emission rates to find total emission rate due to line source on a road

↓

Depiction of total emission rate (kg/h) for NO_x and CO during peak and average traffic conditions on the city map

4.3 STEPS TO COMPUTE EMISSION RATE DUE TO LINE SOURCE

(i) Traffic volume (veh/h)/PCU (passenger car unit) is collected for all the road network by conducting traffic survey. This PCU is converted into traffic volumes of the three vehicle types e.g. TWV, LTV and HTV. PCU is converted into traffic volumes of the three types TWV, LTV and HTV by multiplying PCU with the ratio of traffic volume

of a type of vehicle to the total traffic volume of all the three types. Traffic volumes for all the three types of vehicles are found for peak traffic and average traffic conditions.

Traffic volume of a vehicle type is computed during peak traffic condition by the following formulae:

Traffic volume of a vehicle type during peak traffic hour = (PCU) * [Traffic volume of that particular vehicle during peak hour]/[Total traffic volume of all the vehicle types during peak traffic hour]

Traffic volume of a vehicle type is computed during average traffic condition by the following formulae:

Traffic volume of a vehicle type during average traffic hour = (PCU) * [Traffic volume of that particular type of vehicle during average traffic hour]/[Total traffic volume of all the vehicle types during average traffic hour]

(ii) Traffic volumes computed for TWV, LTV and HTV are being multiplied with the multiplication factors to find out the traffic volumes for TWV, LTV and HTV for the predicted year. A graph (as shown in Fig. 1) is being plotted between the increase in vehicle number of different types and the year. From this graph, it is found that increase in vehicle number for TWV, LTV and HTV over the last five years has been a linear one. Hence, using arithmetic mean method, the multiplication factors are found for TWV, LTV and HTV. Equations are also computed for the relationship

between the number of vehicles and the year for TWV, LTV and HTV. [These multiplication factors and the equations are being given in Table 2]. Once, these multiplication factors are being multiplied with the traffic volumes of TWV, LTV and HTV for the year 1984 (given in Table 1) then traffic volumes of TWV, LTV and HTV for the predicted year 1996 are being obtained.

Traffic volume of a vehicle type for the predicted year is being computed by the following formulae:

Traffic volume of a vehicle type for the year 1996	=	Traffic volume of the same vehicle type for the year 1984	*	Multiplication factor of the same vehicle type

(iii) Speed of a vehicle (in kmph) is being computed for the TWV, LTV and HTV by the Speed-traffic volume equations given in Table 3.

(iv) After computing speed for the TWV, LTV and HTV, the emission factor (in kg/km) is being computed for all the vehicle types. Emission factor (in kg/km) is being computed for the TWV, LTV and HTV by the speed-emission factor equations given in Table 4.

(v) After computing emission factor, the emission rate (in kg/h) is being computed for the TWV, LTV and HTV by the following formulae:

Emission rate (kg/h) of a vehicle type	=	Traffic volume of that vehicle type (vehicles/h)	*	Emission factor of that vehicle type (kg/km/veh)

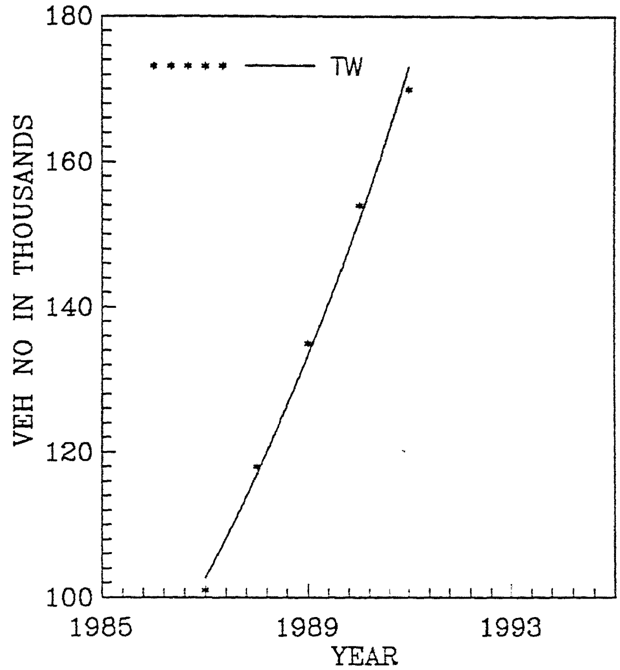
Table:1 Average and Peak Traffic Volumes on Various Roads of Kanpur in 1984.

Road No	Road Name	PCU No/h	No of Vehs/h of Stated Type					
			Av Traffic Vol			Peak Traffic Vol		
			TWV	LTV	HTV	TWV	LTV	HTV
1	Kalyanpur_Rawatpur	2976	267	297	653	624	1041	1309
2	Rawatpur_Eyehosp	4242	381	424	932	890	1484	1866
3	Eyehosp	3234	291	323	711	679	1131	1422
4	Cocacola_Gumti	6870	618	687	1510	1442	2404	3022
5	Gumti_Garibchoki	4110	369	411	904	863	1438	1808
6	Garibchoki_Afimkoti	3978	358	397	874	835	1392	1749
7	Afimkoti_Tatmil	5172	465	517	1137	1086	1810	2275
8	Tatmil_Parachute	5496	494	549	1208	1154	1923	2417
9	Parachute_Ramadevi	2178	196	217	478	457	762	957
10	Ramadevi_Ahirvan	1086	97	108	238	228	380	477
11	Bhauti_Hanuman	888	79	88	194	186	310	390
12	Hanuman_Armapur	1152	103	115	252	241	403	506
13	Armapur_Fazalgn	1500	135	150	328	314	524	658
14	Fazalgn_Garibchoki	3020	271	302	664	634	1056	1328
15	Bingawan_Naubasta	1326	198	185	411	384	371	569
16	Naubasta_Baradevi	1366	204	191	423	396	382	587
17	Baradevi_Juhign	3476	521	486	1077	1008	973	1494
18	Juhign_Afimkoti	11536	1730	1615	3576	3345	3230	4959
19	Afimkoti_Deputypd	3681	552	515	1141	1067	1030	1582
20	Bhauti_Hanumangn	1929	289	308	0.0	752	1176	0.0
21	Hanuman_Nauabsta	2526	378	404	0.0	985	1540	0.0
22	Naubasta_Ramadevi	2400	360	383	0.0	935	1464	0.0
23	Ramadevi_Jajmau	2631	394	420	0.0	1026	1604	0.0
24	Rawatpur_Companybg	1004	120	60	301	361	160	481
25	Companybg_Tafdo	690	82	41	207	248	110	331
26	Tafdo_Barsaiya	690	82	41	207	248	110	331
27	Barsaiya_Phoolbg	690	82	41	207	248	110	331
28	Eyehosp_Benajhber	4130	371	413	908	867	1445	1816
29	Benajhber_Bakarmandi	3870	348	387	850	812	1354	1702
30	Bakarmandi_Chunnign	2596	233	259	570	545	908	1141
31	Chunnign_Parade	4115	370	411	905	864	1440	1810
32	Parade_Barachowraha	5568	501	556	1224	1169	1948	2449
33	Barachowraha_Phoolbg	4305	387	430	947	904	1506	1894
34	Phoolbg_LIC	5000	450	500	1098	1049	1749	2198
35	LIC_Canalrd	4145	373	414	911	870	1450	1823
36	Canalrd_Murry	2807	252	280	617	589	982	1234
37	Chunnygn_Companybg	1854	166	185	407	389	648	815
38	Companybg_Nawabgn	1794	161	179	393	376	627	788
39	Nawabgn_Sabgimandi	876	78	87	191	183	306	385
40	Sabgimandi_Zoo	1190	107	119	260	249	416	522
41	Kidwainagar_Tatmil	4728	425	472	1039	992	1654	2079
42	Tatmil_Ghantaghar	3213	289	321	706	674	1124	1413
43	Ghantaghar_Mallrd	2098	188	209	460	440	734	922
44	Mallrd_Juharidevi	2898	260	289	636	608	1014	1274

Table:1 contd from page 31

Road No	Road Name	PCU No/h	No of Vehs/h of Stated Type					
			Av Traffic Vol			Peak Traffic Vol		
			TWV	LTV	HTV	TWV	LTV	HTV
45	Phoolbg_Circuithouse	1281	153	76	384	461	204	614
46	Circuithouse_Jajmau	570	68	34	171	205	91	273
47	Jajmau_Bypassrd	489	58	29	146	176	78	234
48	Fazalgn_Chawlamkt	2972	267	297	653	624	1040	1307
49	Chawlamkt-Nandlal	3312	298	331	728	695	1159	1456
50	Nandlal_Barra	4104	369	410	902	861	1436	1805
51	Barra_Vishwabank	3078	277	307	676	646	1077	1353
52	Eyehosp_Mariampur	2264	203	226	497	475	792	995
53	Mariampur_Fazalgn	2720	244	272	598	571	951	1196
54	Ghantaghar_Karachi	2898	260	289	636	608	1014	1274
55	Karachi_Phoolbg	2898	260	289	636	608	1014	1274
56	Moolgn_Kotwali	5508	495	550	1211	1156	1927	2423
57	Kotwali_Barachowraha	3108	279	310	683	652	1087	1367
58	Parade_Moolgn	2864	257	286	629	601	1002	1259
59	Moolgn_Ghantaghar	3984	358	398	875	836	1394	1752
60	Bansmandi_Moolgn	3364	302	336	739	706	1177	1479
61	Garibchoki_Bakarmand	1623	146	162	356	340	568	713
62	Gumti_Bakarmandi	3020	271	302	664	634	1056	1328
63	Murry_Parachute	987	118	59	296	355	157	473

TWV: Two Wheeler Vehicle; LTV: Light Transport Vehicle;
HTV: Heavy Transport Vehicle; TVT: Total Vehicular Traffic;



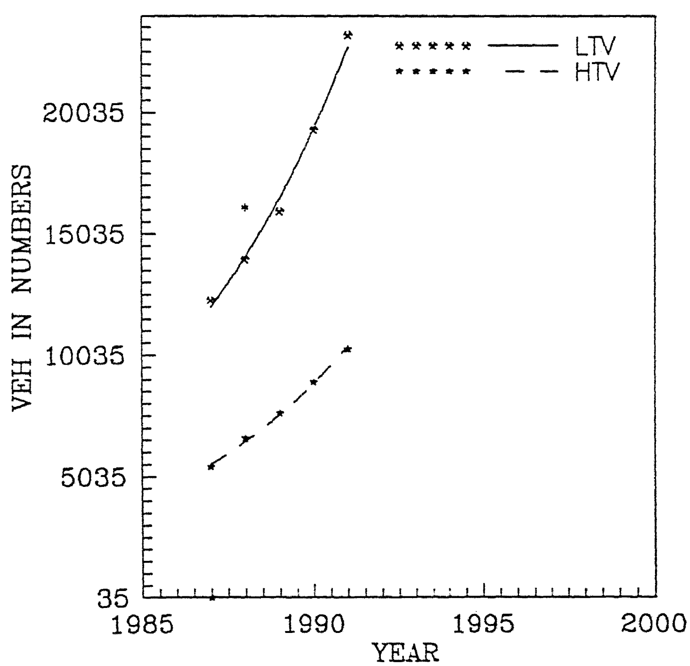


Figure 1   Increase in [illegible]

Table 2. Equations Showing Relationship Between the Number of Vehicles and the Year

$$\phi_{TWV} = \exp(0.130762x) * 1.4819 \exp^{-111}$$

$$\phi_{LTV} = \exp(0.159415x) * 3.26388 \exp^{-134}$$

$$\phi_{HTV} = \exp(0.157560x) * 5.92107 \exp^{-133}$$

x : Year of prediction

ϕ_{TWV} : Number of two wheeler vehicles for the year x

ϕ_{LTV} : Number of light transport vehicles for year x

ϕ_{HTV} : Number of heavy transport vehicles for the year x

Multiplication Factors for Predicting the Number of Vehicles of the Stated Type for the Year 1996

Type of vehicle	Multiplication factor
TWV	2.836
LTV	3.076
HTV	3.28

Table 3. Spped Vs. Traffic Volume Equations

$$\forall_{LTV} = 51.24 - 0.00345\ \phi_{TV}$$

$$\forall_{HTV} = 45.18 - 0.00212\ \phi_{TV}$$

$$\forall_{TWV} = 54.03 - 0.00144\ \phi_{TV}$$

$\forall_{LTV}$: Speed of light transpsort vehicle in kmph

$\forall_{HTV}$: Speed of heavy transpssort vehicle in kmph

$\forall_{TWV}$: Speed of two wheeler vehicle in kmph

ϕ_{TV} : Total traffic volume in number of vehs/h.

Source: Road User Cost STudy in India, CRRI, 1982, Final Report Table-7.11, Delhi.

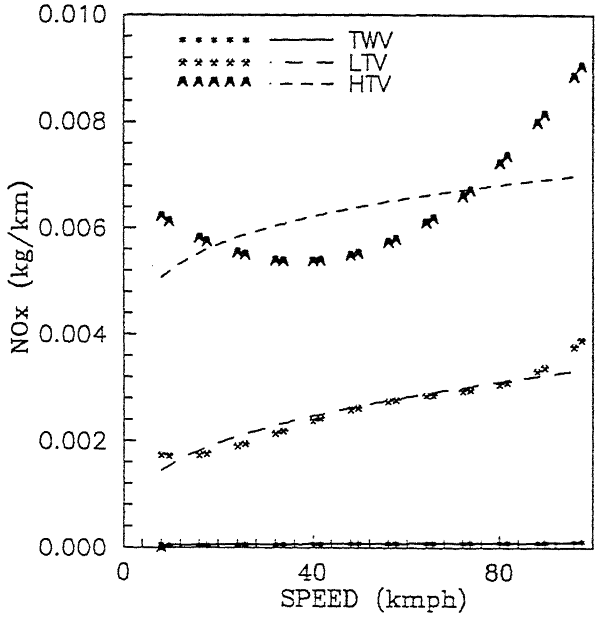


Figure 2. Change in Emission Factor with the Change in Speed for NOx

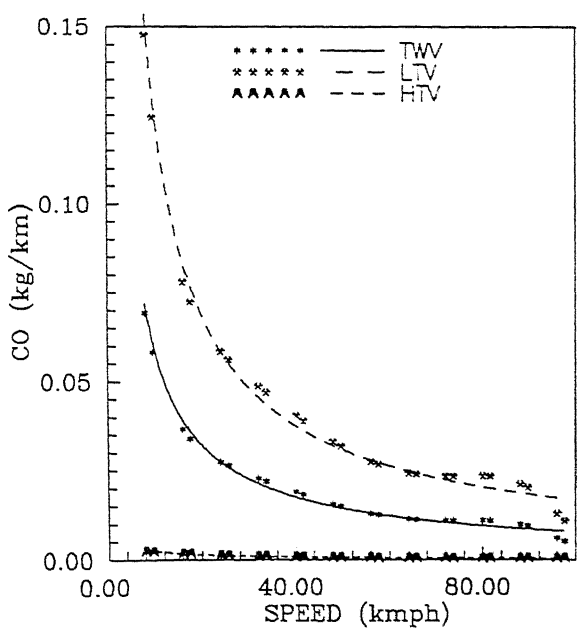


Figure 3. Change in Emission Factor with the Change in Speed for CO

Table 4. Speed Vs. Emission Factor Equations for NO_x

$$q_{TWV} = 4.2 * 10^{-5} + 6.6 * 10^{-7} * V_{TWV}$$

$$q_{LTV} = 0.0016 * \exp(0.00877 * V_{LTV})$$

$$q_{HTV} = 0.00675 - 7.4 * 10^{-5} V_{HTV} + 9.98 * 10^{-7} * (V_{HTV})^{2}$$

Speed Vs. Emission Factor Equations for CO

$$q_{TWV} = 0.444 * (V_{TWV})^{-0.875}$$

$$q_{LTV} = 0.947 * (V_{LTV})^{-0.875}$$

$$q_{HTV} = 0.00414 - 0.000858 \text{ Log } V_{HTV}$$

q_{TWV} : Emission factor in kg/km for two wheeler vehicle

q_{LTV} : Emission factor in kg/km for light transport vehicle

q_{HTV} : Emission factor in kg/km for heavy transpsort vehicle

V_{TWV} : Speed of two wheeler vehicle in kmph

V_{LTV} : Speed of light transport vehicle in kmph

V_{HTV} : Speed of heavy transport vehicle in kmph

Source: Indian Institute of Petroleum, Dehradun.

Table: 5 NOx Emissions due to Vehicular Transport at Average Traffic Volumes.

Road NO	Road Name	TWV	LTV	HTV	TVT
1	Kalyanpur_Rawatpur	0.05	2.03	12.08	14.17
2	Rawatpur_Eyehosp	0.07	2.76	17.23	20.06
3	Eyehosp	0.06	2.19	13.13	15.37
4	Cocacola_Gumti	0.10	4.02	28.18	32.29
5	Gumti_Garibchoki	0.07	2.68	16.69	19.44
6	Garibchoki_Afimkoti	0.07	2.61	16.16	18.84
7	Afimkoti_Tatmil	0.08	3.24	21.06	24.38
8	Tatmil_Parachute	0.08	3.40	22.40	25.88
9	Parachute_Ramadevi	0.04	1.54	8.85	10.43
10	Ramadevi_Ahirvan	0.02	0.80	4.43	5.25
11	Bhauti_Hanuman	0.02	0.66	3.62	4.29
12	Hanuman_Armapur	0.02	0.85	4.69	5.56
13	Armapur_Fazalgn	0.03	1.09	6.11	7.22
14	Fazalgn_Garibchoki	0.05	2.06	12.26	14.38
15	Bingawan_Naubasta	0.04	1.32	7.26	8.63
16	Naubasta_Baradevi	0.04	1.36	7.48	8.88
17	Baradevi_Juhign	0.09	3.08	19.04	22.20
18	Juhign_Afimkoti	0.24	8.07	70.92	79.24
19	Afimkoti_Deputypd	0.09	3.22	20.17	23.49
20	Bhauti_Hanumangn	0.06	2.25	0.00	2.31
21	Hanuman_Nauabsta	0.08	2.90	0.00	2.98
22	Naubasta_Ramadevi	0.08	2.76	0.00	2.84
23	Ramadevi_Jajmau	0.08	3.01	0.00	3.09
24	Rawatpur_Companybg	0.03	0.44	5.33	5.80
25	Companybg_Tafdo	0.02	0.31	3.67	3.99
26	Tafdo_Barsaiya	0.02	0.31	3.67	3.99
27	Barsaiya_Phoolbg	0.02	0.31	3.67	3.99
28	Eyehosp_Benajhber	0.07	2.70	16.78	19.54
29	Benajhber_Bakarmandi	0.06	2.55	15.71	18.33
30	Bakarmandi_Chunnign	0.05	1.80	10.55	12.39
31	Chunnign_Parade	0.07	2.69	16.72	19.47
32	Parade_Barachowraha	0.08	3.43	22.70	26.22
33	Barachowraha_Phoolbg	0.07	2.79	17.49	20.35
34	Phoolbg_LIC	0.08	3.15	20.34	23.57
35	LIC_Canalrd	0.07	2.70	16.84	19.62
36	Canalrd_Murry	0.05	1.93	11.40	13.38
37	Chunnygn_Companybg	0.03	1.33	7.54	8.90
38	Companybg_Nawabgn	0.03	1.28	7.30	8.61
39	Nawabgn_Sabgimandi	0.02	0.65	3.57	4.24
40	Sabgimandi_Zoo	0.02	0.87	4.85	5.74
41	Kidwainagar_Tatmil	0.08	3.01	19.22	22.31
42	Tatmil_Ghantaghar	0.06	2.18	13.05	15.28
43	Ghantaghar_Mallrd	0.04	1.49	8.53	10.05
44	Mallrd_Juharidevi	0.05	1.99	11.77	13.81
45	Phoolbg_Circuithouse	0.03	0.56	6.80	7.39

Table:5 Contd on Page 39

Table:5 Contd from Page 38

Road NO	Road Name	TWV	LTV	HTV	TVT
46	Circuithouse_Jajmau	0.02	0.25	3.03	3.30
47	Jajmau_Bypassrd	0.01	0.22	2.60	2.84
48	Fazalgn_Chawlamkt	0.05	2.03	12.07	14.15
49	Chawlamkt-Nandlal	0.06	2.23	13.45	15.74
50	Nandlal_Barra	0.07	2.68	16.67	19.42
51	Barra_Vishwabank	0.05	2.09	12.50	14.65
52	Eyehosp_Mariampur	0.04	1.59	9.20	10.83
53	Mariampur_Fazalgn	0.05	1.88	11.05	12.97
54	Ghantaghar_Karachi	0.05	1.99	11.77	13.81
55	Karachi_Phoolbg	0.05	1.99	11.77	13.81
56	Moolgn_Kotwali	0.08	3.40	22.45	25.93
57	Kotwali_Barachowraha	0.05	2.11	12.62	14.79
58	Parade_Moolgn	0.05	1.97	11.63	13.65
59	Moolgn_Ghantaghar	0.07	2.62	16.18	18.87
60	Bansmandi_Moolgn	0.06	2.26	13.66	15.98
61	Garibchoki_Bakarmand	0.03	1.17	6.60	7.80
62	Gumti_Bakarmandi	0.05	2.06	12.26	14.38
63	Murry_Parachute	0.03	0.43	5.24	5.70

TWV:Two Wheeler Vehicle; LTV:Light Transport Vehicle;
HTV:Heavy Transport Vehicle; TVT:Total Vehicular Traffic.

Table: 6 NOx Emissions due to Vehicular Transport at Peak Traffic Volumes.

Road NO	Road Name	TWV	LTV	HTV	TVT
1	Kalyanpur_Rawatpur	0.09	6.00	25.03	31.12
2	Rawatpur_Eyehosp	0.12	7.57	36.67	44.36
3	EyeHosp	0.10	6.36	27.32	33.78
4	Cocacola_Gumti	0.20	12.02	65.25	77.47
5	Gumti_Garibchoki	0.12	7.43	35.40	42.95
6	Garibchoki_Afimkoti	0.12	7.28	34.15	41.54
7	Afimkoti_Tatmil	0.15	9.05	46.03	55.23
8	Tatmil_Parachute	0.16	9.62	49.50	59.27
9	Parachute_Ramadevi	0.08	4.75	18.14	22.96
10	Ramadevi_Ahirvan	0.05	2.63	9.02	11.69
11	Bhauti_Hanuman	0.04	2.19	7.38	9.61
12	Hanuman_Armapur	0.05	2.77	9.57	12.39
13	Armapur_Fazalgn	0.06	3.49	12.45	16.00
14	Fazalgn_Garibchk	0.09	6.07	25.41	31.57
15	Bingawan_Naubasta	0.07	2.52	10.54	13.13
16	Naubasta_Baradevi	0.08	2.58	10.85	13.51
17	Baradevi_Juhign	0.14	5.37	28.17	33.68
18	Juhign_Afimkoti	0.46	16.15	112.59	129.20
19	Afimkoti_Deputypd	0.15	5.58	29.95	35.68
20	Bhauti_Hanumangn	0.14	7.61	0.00	7.75
21	Hanuman_Nauabsta	0.16	9.45	0.00	9.61
22	Naubasta_Ramadevi	0.16	9.08	0.00	9.24
23	Ramadevi_Jajmau	0.17	9.75	0.00	9.92
24	Rawatpur_Companybg	0.07	1.13	8.51	9.70
25	Companybg_Tafdo	0.05	0.79	5.86	6.70
26	Tafdo_Barsaiya	0.05	0.79	5.86	6.70
27	Barsaiya_Phoolbg	0.05	0.79	5.86	6.70
28	Eyehosp_Benajhber	0.12	7.45	35.59	43.16
29	Benajhber_Bakarmandi	0.11	7.16	33.13	40.40
30	Bakarmandi_Chunnign	0.09	5.43	21.72	27.24
31	Chunnign_Parade	0.12	7.43	35.44	42.99
32	Parade_Barachaura	0.16	9.74	50.28	60.19
33	Barachaura_Phoolbag	0.12	7.63	37.28	45.03
34	Phoolbag_LIC	0.14	8.75	44.23	53.12
35	LIC_Canalrd	0.12	7.46	35.73	43.32
36	Canalrd_Murry	0.09	5.76	23.54	29.39
37	Chunnygn_Comapnybg	0.07	4.17	15.41	19.65
38	Companybg_Nawabgn	0.07	4.06	14.91	19.03
39	Nawabgn_Sabgimandi	0.04	2.17	7.28	9.49
40	Sabgimandi_Zoo	0.05	2.85	9.88	12.79
41	Kidwaingr_Tatmil	0.14	8.27	41.46	49.87
42	Tatmil_Ghantaghar	0.10	6.33	27.13	33.56
43	Ghantaghar_Mallrd	0.08	4.61	17.46	22.15

Table:6 Contd on Page 41

Table:6 Contd from Page 40

Road NO	Road Name	TWV	LTV	HTV	TVT
44	Mallrd_Juharidevi	0.09	5.89	24.34	30.32
45	Phoolbg_Circuithouse	0.09	1.40	10.84	12.33
46	Circuithouse_Jajmau	0.04	0.66	4.84	5.55
47	Jajmau_Bypassrd	0.04	0.58	4.15	4.77
48	Fazalgn_Chawlamkt	0.09	6.00	24.99	31.08
49	Chalwamkt-Nandlal	0.10	6.47	28.01	34.57
50	Nandlal_Barra	0.12	7.42	35.34	42.88
51	Barra_Vishwabank	0.09	6.15	25.93	32.17
52	Eyehosp_Mariampur	0.08	4.89	18.87	23.84
53	Mariampur_Fazalgn	0.09	5.63	22.78	28.50
54	Ghantaghar_Karachi	0.09	5.89	24.34	30.32
55	Karachi_Phoolbg	0.09	5.89	24.34	30.32
56	Moolgn_Kotwali	0.16	9.64	49.63	59.43
57	Kotwali_Barachowraha	0.10	6.19	26.19	32.48
58	Parade_Moolgn	0.09	5.84	24.04	29.97
59	Moolgn_Ghantaghar	0.12	7.29	34.20	41.60
60	Bansmandi_Moolgn	0.10	6.53	28.48	35.12
61	Garibchoki_Bakarmand	0.06	3.73	13.48	17.27
62	Gumti_Bakarmandi	0.09	6.07	25.41	31.57
63	Murry_Parachute	0.07	1.11	8.36	9.54

TWV:Two Wheeler Vehicle; LTV:Light Transport Vehicle;
HTV:Heavy Transport Vehicle; TVT:Total Vehicular Traffic.

Table:7 CO Emissions due to Vehicular Transport at Average Traffic Volumes

Road No	Road Name	TWV	LTV	HTV	TVT
1	Kalyanpur_Rawatpur	12.93	35.90	6.26	55.09
2	Rawatpur_Eyehosp	21.90	59.14	9.00	90.04
3	Eyehosp	14.52	40.09	6.81	61.42
4	Cocacola_Gumti	60.04	144.40	14.91	219.35
5	Gumti_Garibchoki	20.82	56.40	8.71	85.94
6	Garibchoki_Afimkoti	19.77	53.71	8.43	81.91
7	Afimkoti_Tatmil	31.12	81.65	11.06	123.83
8	Tatmil_Parachute	35.09	91.02	11.78	137.90
9	Parachute_Ramadevi	8.61	24.22	4.55	37.39
10	Ramadevi_Ahirvan	3.84	10.95	2.25	17.04
11	Bhauti_Hanumant	3.07	8.80	1.84	13.71
12	Hanuman_Armapur	4.10	11.67	2.39	18.16
13	Armapur_Fazalgn	5.52	15.67	3.12	24.31
14	Fazalgn_Garibchoki	13.19	36.58	6.35	56.12
15	Bingawan_Naubasta	8.48	20.11	3.72	32.31
16	Naubasta_Baradevi	8.79	20.82	3.84	33.44
17	Baradevi_Juhign	33.45	74.35	9.98	117.78
18	Juhign_Afimkoti	287.92	2545.78	38.01	2871.71
19	Afimkoti_Deputypd	37.28	82.08	10.59	129.96
20	Bhauti_Hanumangn	11.65	31.82	0.00	43.47
21	Hanuman_Nauabsta	15.93	43.27	0.00	59.20
22	Naubasta_Ramadevi	14.99	40.78	0.00	55.77
23	Ramadevi_Jajmau	16.73	45.34	0.00	62.07
24	Rawatpur_Companybg	4.75	6.10	2.71	13.57
25	Companybg_Tafdo	3.15	4.06	1.86	9.07
26	Tafdo_Barsaiya	3.15	4.06	1.86	9.07
27	Barsaiya_Phoolbg	3.15	4.06	1.86	9.07
28	Eyehosp_Benajhber	20.98	56.81	8.76	86.56
29	Benajhber_Bakarmandi	18.92	51.59	8.19	78.70
30	Bakarmandi_Chunnign	10.78	30.11	5.44	46.33
31	Chunnign_Parade	20.86	56.48	8.73	86.07
32	Parade_Barachowraha	36.07	93.24	11.95	141.26
33	Barachaura_Phoolbg	22.44	60.52	9.14	92.11
34	Phoolbg_LIC	29.18	77.08	10.68	116.94
35	LIC_Canalrd	21.09	57.14	8.79	87.03
36	Canalrd_Murry	11.95	33.27	5.89	51.11
37	Chunnygn_Companybg	7.09	20.02	3.87	30.97
38	Companybg_Nawabgn	6.80	19.24	3.74	29.78
39	Nawabgn_Sabgimandi	3.03	8.66	1.81	13.51
40	Sabgimandi_Zoo	4.24	12.11	2.47	18.82
41	Kidwaingr_Tatmil	26.35	70.21	10.07	106.63
42	Tatmil_Ghantaghar	14.40	39.76	6.77	60.93

Table:7 Contd on Page 43

Table:7 Contd from Page 42

Road No	Road Name	TWV	LTV	HTV	TVT
43	Ghantaghar_Mallrd	8.23	23.18	4.38	35.79
44	Mallrd_Juharidevi	12.47	34.68	6.09	53.24
45	Phoolbg_Circuithouse	6.26	8.00	3.47	17.73
46	Circuithouse_Jajmau	2.57	3.32	1.53	7.42
47	Jajmau_Bypassrd	2.19	2.82	1.32	6.33
48	Fazalgn_Chawlamkt	12.91	35.85	6.25	55.01
49	Chawlamkt-Nandlal	15.02	41.41	6.98	63.42
50	Nandlal_Barra	20.76	56.27	8.70	85.74
51	Barra_Visvabank	13.55	37.52	6.48	57.55
52	Eyehosp_Mariampur	9.04	25.41	4.74	39.19
53	Mariampur_Fazalgn	11.46	31.94	5.71	49.11
54	Ghantaghar_Karachi	12.47	34.68	6.09	53.24
55	Karachi_Phoolbg	12.47	34.68	6.09	53.24
56	Moolgn_Kotwali	35.25	91.41	11.81	138.47
57	Kotwali_Barachowraha	13.74	38.04	6.54	58.32
58	Parade_Moolgn	12.29	34.13	6.02	52.43
59	Moolgn_Ghantaghar	19.80	53.83	8.44	82.08
60	Bansmandi_Moolgn	15.36	42.31	7.09	64.76
61	Garibchoki_Bakarmandi	6.05	17.15	3.38	26.58
62	Gumti_Bakarmandi	13.19	36.58	6.35	56.12
63	Murry_Parachute	4.66	5.99	2.67	13.32

TWV: Two Wheeler Vehicle; LTV: Light Transport Vehicle;
HTV: Heavu Transport Vehicle; TVT: Total Vehicular Traffic.

Table:8 CO Emissions due to Vehicular Transport at Peak Traffic Volumes

Road No	Road Name	TWV	LTV	HTV	TVT
1	Kalyanpur_Rawatpur	68.04	237.44	13.26	318.75
2	Rawatpur_Eyehosp	148.21	1228.19	19.54	1395.95
3	Eyehosp	92.46	299.74	14.51	406.70
4	Cocacola_Gumti	240.04	3790.74	35.48	4066.26
5	Gumti_Garibchoki	143.58	914.64	18.86	1077.08
6	Garibchoki_Afimkoti	139.00	723.63	18.19	880.82
7	Afimkoti_Tatmil	180.72	2853.82	24.58	3059.12
8	Tatmil_Parachute	192.04	3032.18	26.47	3250.69
9	Parachute_Ramadevi	31.37	122.88	9.54	163.79
10	Ramadevi_Ahirvan	10.58	44.35	4.66	59.59
11	Bhauti_Hanuman	8.18	34.58	3.79	46.55
12	Hanuman_Armapur	11.46	47.82	4.95	64.23
13	Armapur_Fazalgn	16.63	68.28	6.48	91.39
14	Fazalgn_Garibchoki	71.45	246.82	13.47	331.74
15	Bingawan_Naubasta	19.06	45.80	5.46	70.32
16	Naubasta_Baradevi	19.87	47.65	5.63	73.16
17	Baradevi_Juhign	167.69	291.59	14.97	474.25
18	Juhign_Afimkoti	556.65	5092.07	66.16	5714.88
19	Afimkoti_Deputypd	177.61	362.71	15.93	556.25
20	Bhauti_Hanumangn	44.00	166.71	0.00	210.70
21	Hanuman_Nauabsta	73.00	264.10	0.00	337.10
22	Naubasta_Ramadevi	65.62	240.21	0.00	305.84
23	Ramadevi_Jajmau	79.87	285.80	0.00	365.67
24	Rawatpur_Companybg	16.22	18.19	4.38	38.79
25	Companybg_Tafdo	10.29	11.65	3.00	24.93
26	Tafdo_Barsaiya	10.29	11.65	3.00	24.93
27	Barsaiya_Phoolbg	10.29	11.65	3.00	24.93
28	Eyehosp_Benajhber	144.28	952.38	18.97	1115.63
29	Benajhber_Bakarmandi	135.19	614.16	17.64	766.98
30	Bakarmandi_Chunnign	46.23	172.67	11.47	230.37
31	Chunnign_Parade	143.75	923.79	18.89	1086.43
32	Parade_Barachowraha	194.57	3072.16	26.90	3293.62
33	Barachowraha_Phoolbg	150.38	1462.25	19.87	1632.51
34	Phoolbg_LIC	174.68	2758.48	23.61	2956.77
35	LIC_Canalrd	144.81	982.11	19.04	1145.96
36	Canalrd_Murry	56.90	205.65	12.46	275.01
37	Chunnygn_Companybg	23.34	93.84	8.07	125.25
38	Companybg_Nawabgn	22.07	89.09	7.80	118.95
39	Nawabgn_Sabgimandi	8.05	34.01	3.74	45.80
40	Sabgimandi_Zoo	11.96	49.88	5.11	66.96
41	Kidwainagar_Tatmil	165.17	2608.82	22.12	2796.11
42	Tatmil_Ghantaghar	89.97	293.92	14.40	398.29
43	Ghantaghar_Mallrd	29.17	115.08	9.17	153.42

Table:8 Contd on Page 45

Table:8 Contd from Page 44

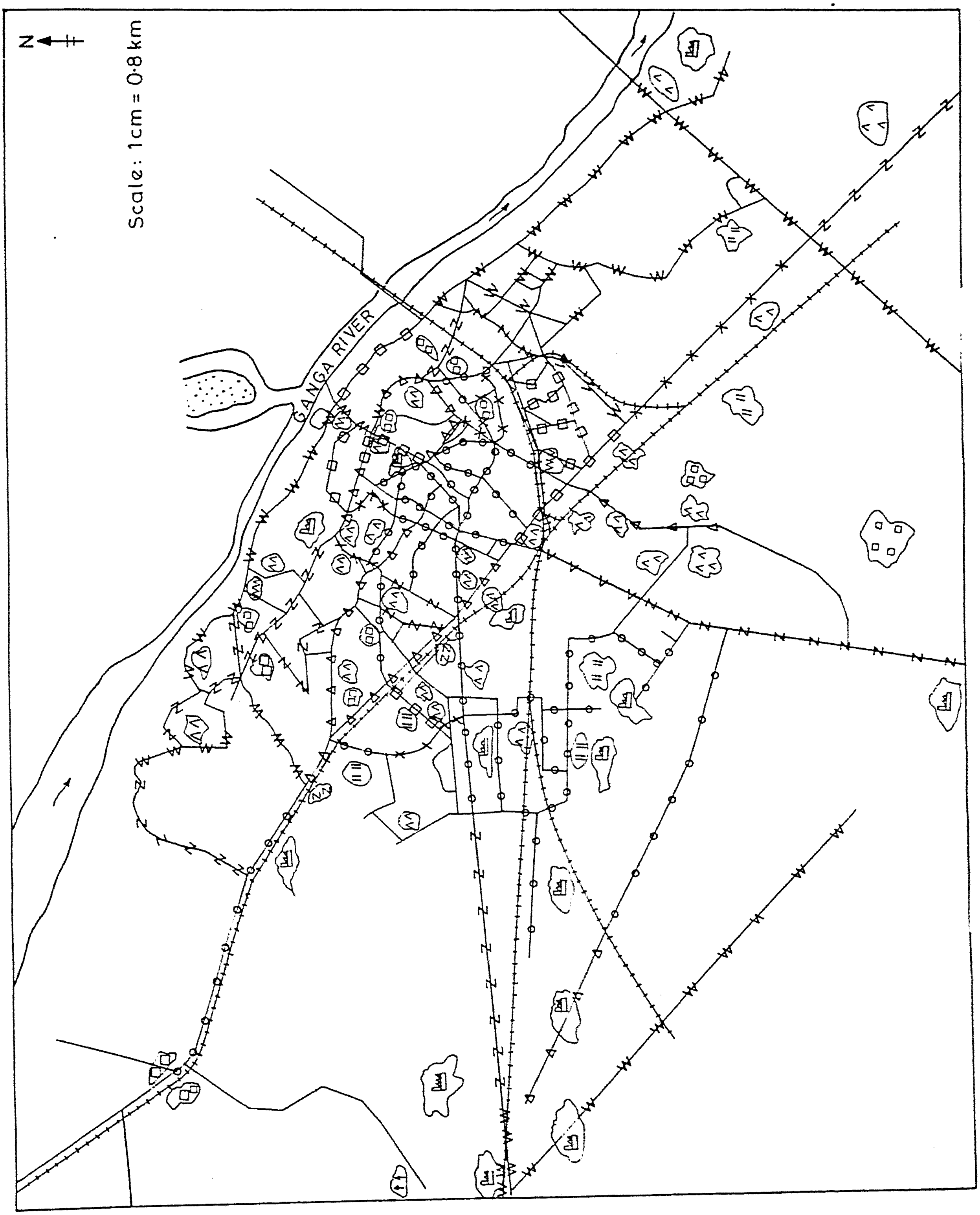
Road No	Road Name	TWV	LTV	HTV	TVT
44	Mallrd_Juharidevi	62.53	222.01	12.90	297.44
45	Phoolbg_Circuithouse	22.34	24.78	5.61	52.74
46	Circuithouse_Jajmau	8.25	9.38	2.47	20.10
47	Jajmau_Bypassrd	6.95	7.91	2.11	16.98
48	Fazalgn_Chawlamkt	67.77	236.68	13.25	317.70
49	Chawlamkt-Nandlal	102.53	322.82	14.88	440.23
50	Nandlal_Barra	143.40	904.70	18.83	1066.93
51	Barra_Vishwabank	76.38	259.81	13.75	349.94
52	Eyehosp_Mariampur	33.93	131.83	9.93	175.69
53	Mariampur_Fazalgn	52.12	191.20	12.05	255.37
54	Ghantaghar_Karachi	62.53	222.01	12.90	297.44
55	Karachi_Phoolbg	62.53	222.01	12.90	297.44
56	Moolgn_Kotwali	192.45	3038.84	26.54	3257.84
57	Kotwali_Barachowraha	79.13	266.98	13.90	360.01
58	Parade_Moolgn	60.35	215.74	12.73	288.82
59	Moolgn_Ghantaghar	139.18	730.71	18.22	888.11
60	Bansmandi_Moolgn	110.38	339.81	15.13	465.32
61	Garibchoki_Bakarmandi	18.76	76.56	7.03	102.35
62	Gumti_Bakarmandi	71.45	246.82	13.47	331.74
63	Murry_Parachute	15.86	17.79	4.30	37.96

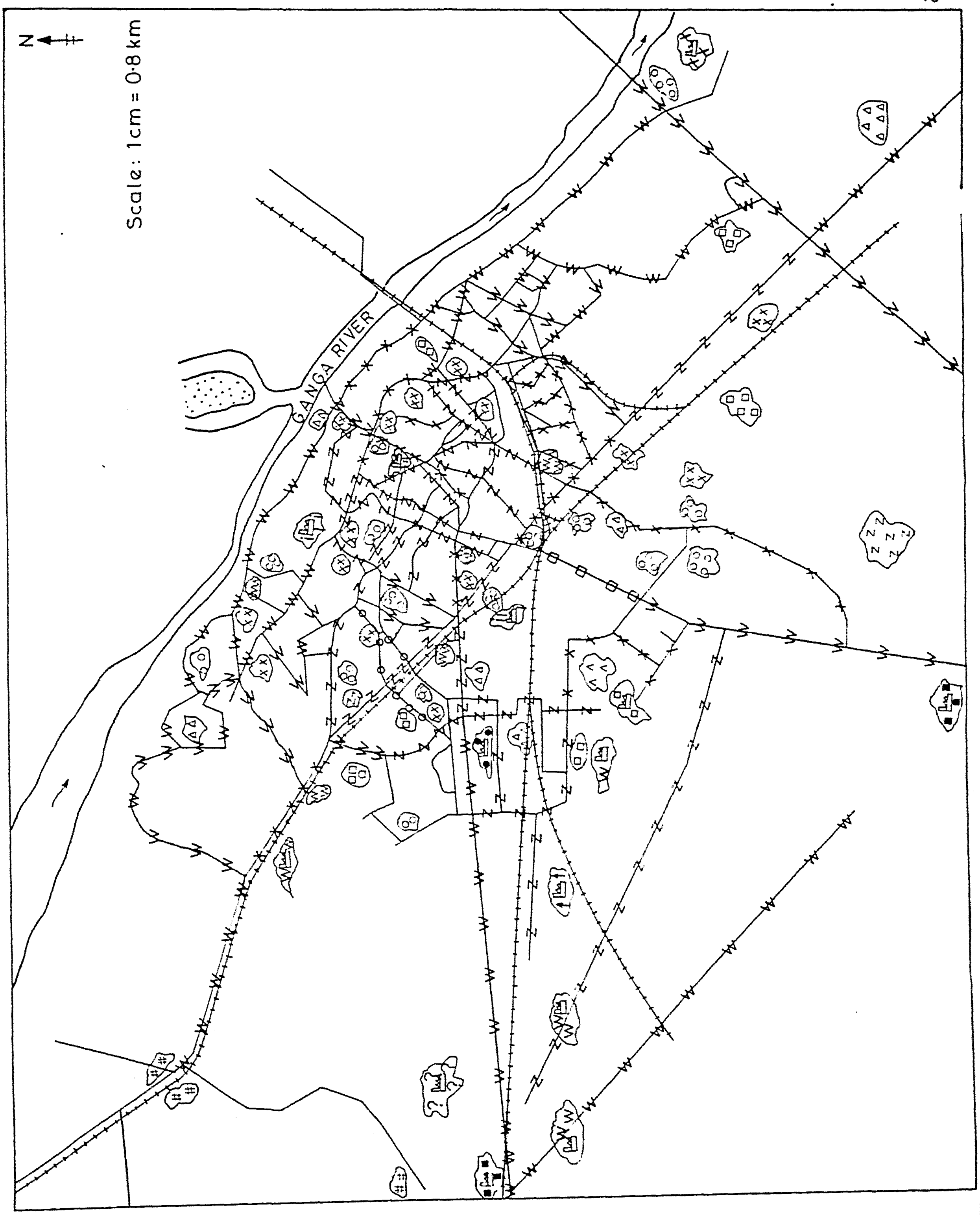
TWV: Two Wheeler Vehicle; LTV: Light Transport Vehicle;
HTV: Heavu Transport Vehicle; TVT: Total Vehicular Traffic.

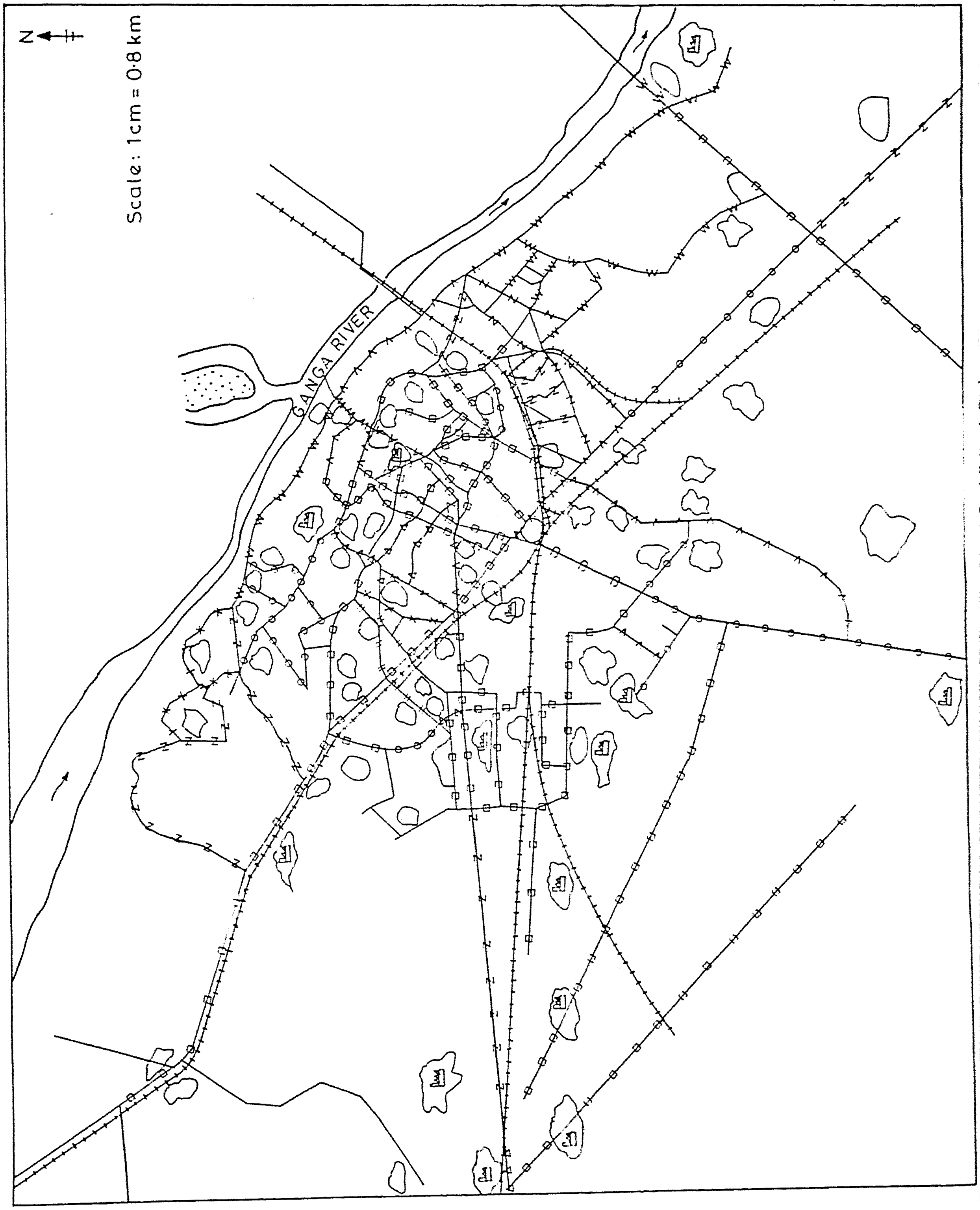
LEGEND

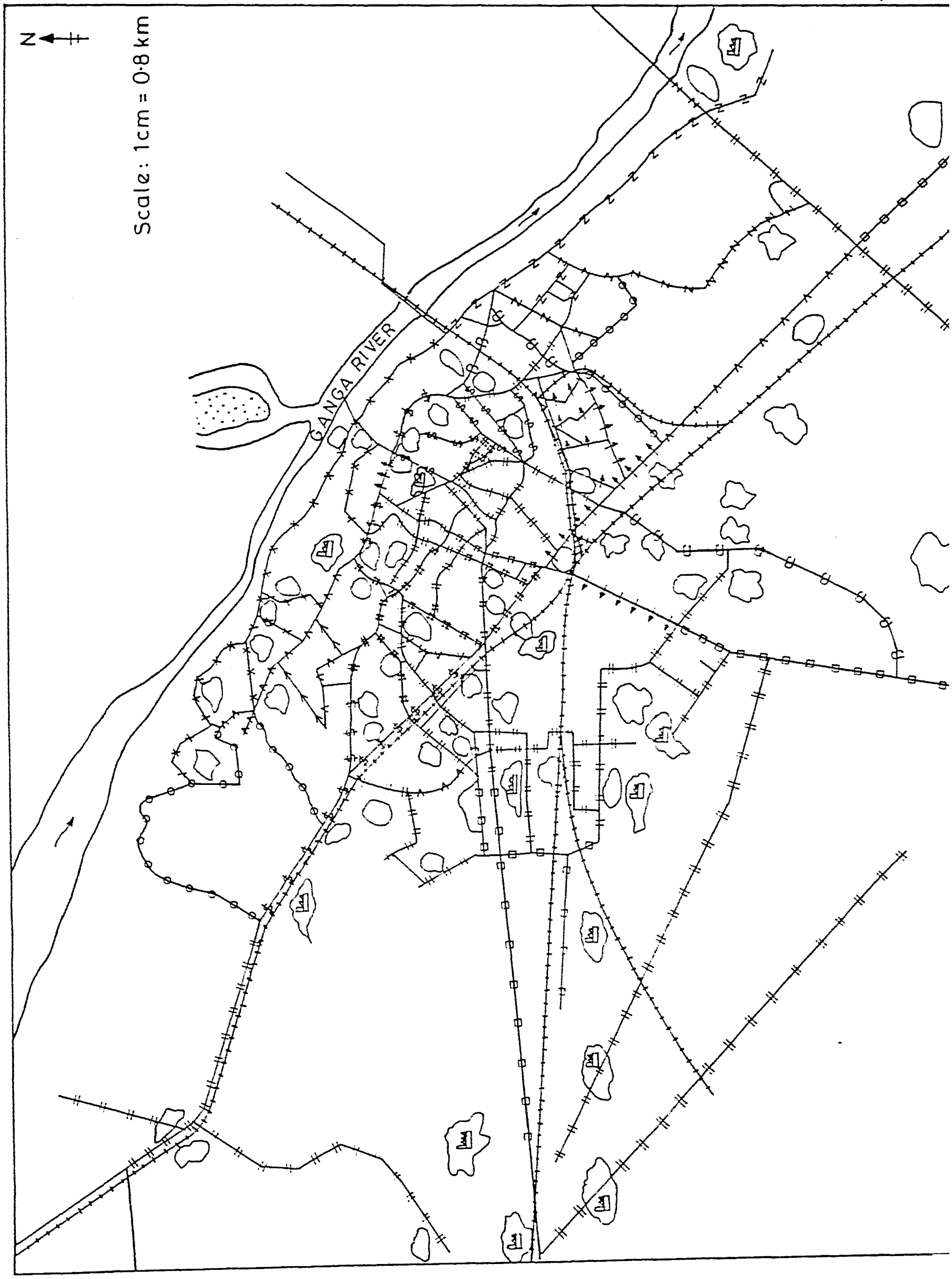
Symbol	Emission Rate (kg/hr)
W W W	0 - 10
Z Z Z	11 - 20
X X X	21 - 30
o o o	31 - 40
Δ Δ Δ	41 - 50
□ □ □	51 - 100
Λ Λ Λ	101 - 200
ǁ ǁ ǁ	201 - 500
# # #	501 - 1000
S S S	1001 - 2000
ß ß ß	2001 - 3000
↑ ↑ ↑	3001 - 4000
Δ Δ Δ	4001 - 10 000
□ □ □	10,001 - 50,000
o o o	50,001 - 100,000
i i i	100,001 - 200,0000
? ? ?	200,0001 >

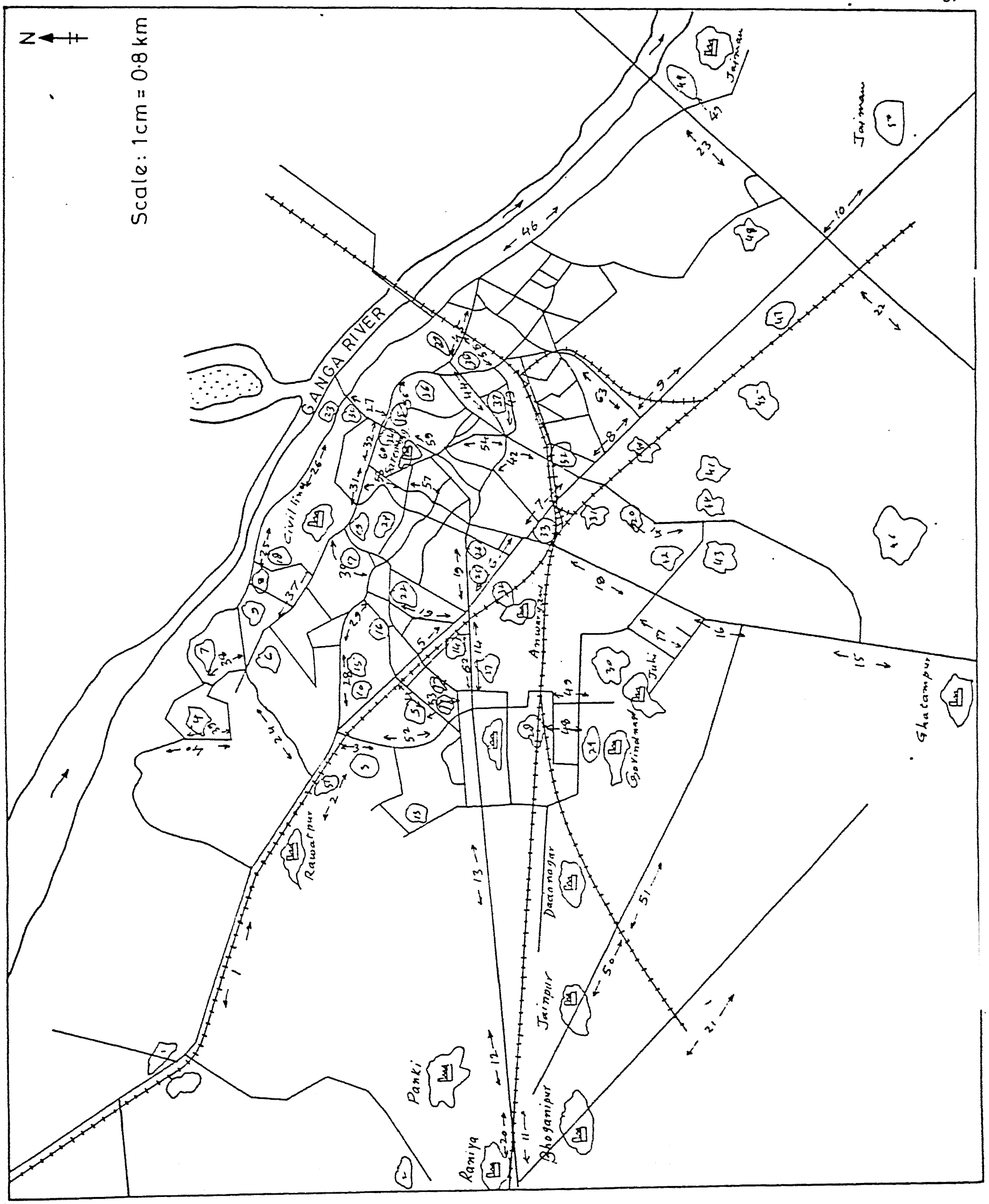
Figure 4.


N
Scale: 1 cm = 0·8 km
GANGA RIVER


N
Scale: 1cm = 0·8 km
GANGA RIVER


N
Scale: 1cm = 0·8 km
GANGA RIVER


Scale: 1cm = 0·8 km
N
GANGA RIVER


N
Scale: 1cm = 0·8 km
GANGA RIVER
Civil lines
Rawatpur
Panki
Raniya
Bhoganipur
Jainpur
Dadanagar
Anwarganj
Govindnagar
Juhi
Ghatampur
Jajmau

(vi) After computing emission rate for the TWV, LTV and HTV, the emission rates are summed up to give the total emission rate due to all vehicle types on a road.

4.4 FLOW CHART FOR COMPUTATION OF EMISSION RATE DUE TO AREA SOURCE

Collection of ward wise population of Kanpur city for the last ten years and projection of the population on a graph against the year (Fig. 9)

↓

Finding the equations from the above graph (Fig. 9) showing relationship between the population number and the year for HIG, LIG and MIG. Finding the type of increase in population for HIG, LIG and MIG and the multiplication factors for the predicted year for HIG, LIG and MIG

↓

Computation of the number of fuel units and percentage users of different fuel types e.g. cowdung, wood, kerosene oil, coal and LPG from the population data and the socio-economic survey data respectively (Tables 10 and 11)

↓

Computation of the estimated, average, domestic fuel consumption rates for cowdung, wood, k. oil, coal and LPG from the socio-economic survey data (Table 12)

↓

Computation of the ward wise, average, and peak NO_x emission rates from the fuel units, fuel consumption rates and emission factors (Table 13, 14 and 15)

4.5 STEPS TO COMPUTE EMISSION RATE DUE TO AREA SOURCE

(i) Ward wise population of Kanpur city is collected from municipal authority. This population is collected for different income group e.g. high income group, middle income group and low income group (HIG, MIG and LIG). This population data based on income group wise is projected on a graph against the year as shown in Fig. 9. From the graph it is found that the increase in population for HIG, MIG and LIG has been a linear one. Hence, using arithmetic mean method the multiplication factors for predicting the population number for 1996 are found for HIG, MIG and LIG. These multiplication factors are given in Table 9.

(ii) It is being assumed that HIG and MIG people use only LPG as a domestic fuel. LIG people use different types of domestic fuel e.g. cowdung, wood, kerosene oil, coal and LPG. A socio-economic survey is being conducted to find out the following details:

(a) Percentage users of different types of domestic fuel among low income group people.

(b) Estimated average domestic fuel consumption rates among low income group for different types of fuels.

(c) Number of persons in a household using a fuel unit.

(d) Number of hours, a fuel unit is being used.

(iii) The above details are found out and used to compute the number of fuel units of different types in the following way:

(a) Ward wise population is being divided by five (5.0) to give the total number of fuel units. As it is being found from the socio-economic survey data that five persons use one fuel unit.

(b) This total number of fuel units is being multiplied with the percentage users of different types of fuel units. This gives the number of fuel units of different types in each ward. The total number of fuel units and their percentage distribution ward wise is being given in Table 11. This percentage users of different types of fuel units among LIG is found from the survey data. Since, LPG fuel is being used by LIG, HIG and MIG people also, hence, percentage users of LPG is summed up in all the cases of LIG, HIG and MIG. Finally, percentage users of different types of fuel units of all the income group is being summarised in Table 11.

(v) Number of fuel units of different types is being multiplied with the estimated average domestic fuel consumption rates of corresponding fuel types. This estimated, average, domestic fuel consumption rate for different types of fuel is being given in Table 12. After such multiplication, the daily, average, consumption of different fuel types, is obtained ward wise. Since, from the survey, it is found that a fuel unit is being consumed for six hours a day, hence, the daily, average consumption of different fuel

types is being divided by six (6.0) to give the fuel consumption of different fuel types, during peak hours (in kg/h) and when the daily, average, consumption of different fuel types, is being divided by twenty four (24.0) then fuel consumption of different fuel types, during average period, (in kg/h) is obtained.

(vi) Ward wise, fuel consumption rates, of different fuel types, during peak and average hour are being multiplied with the emission factors to give the emission rates, ward wise, due to different fuel types. The emission rates computed in this way due to different fuel types are summed up to give the total emission rate, ward wise, during peak and average hour. The emission factors due to various fuels are given in Table 13. The formulae for computing emission rate for NO_x for a fuel type is given below:

Emission rate (kg/h) of a fuel type	=	Fuel consumption rate (kg/h) of that fuel type	*	Emission factor of that fuel type (kg/kg)

4.6 FLOW CHART FOR COMPUTING NO_x EMISSION RATES DUE TO INDUSTRIAL SOURCES

Finding the number of industrial units and their fuel consumption rates for different fuel types as low diesel oil, coal, wood and diesel (Table 16)

↓

Computation of the area wise, average NO_x emission rates from the fuel consumption rates and emission factors (Table 17)

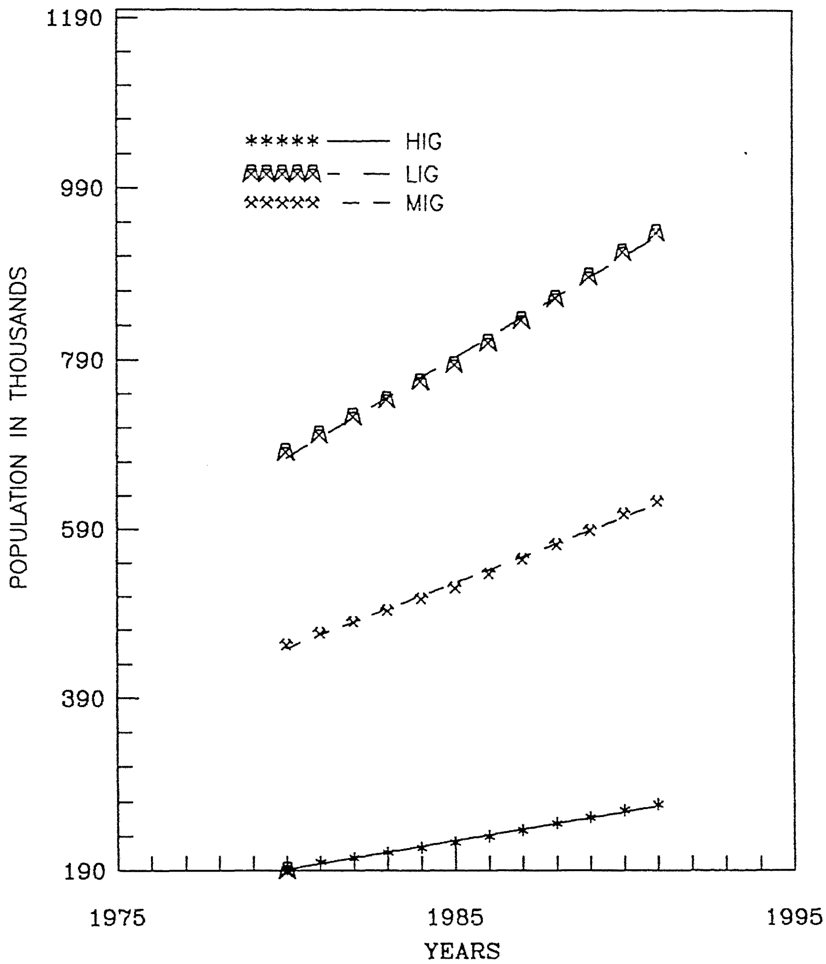


Figure 1a Increase in Population Over the Last Ten Years

Source : Kanpur Municipal Corporation, Kanpur

Table 9. Equations Showing Relationship between the Population Numbeer and the Year

$$P_{HIG} = 132522 * LN(x) + (- 100404)$$

$$P_{LIG} = 46601.6 * LN(x) + (- 353072)$$

$$P_{HIG} = 30891.9 * LN(x) + (- 234048)$$

x : year

P_{HIG} : Population number of high income group

P_{LIG} : Population number of low income group

P_{MIG} : Population number of middle income group

Multiplication Factors for Predicting the Population Number of the Stated Type for the Year 1996

Type of income group of population	Multiplication factor
HIG	1.142
LIG	1.140
MIG	1.1405

Table: 10 Ward Wise Estimated Population for 1991 and 1996.

Ward No	Ward Name	Population in Thousands	
		1991	1996
1	Kalyanpur	547.50	624.08
2	Panki	808.50	921.81
3	Rawatpur	67.50	77.67
4	Nawabgn	49.50	56.70
5	Kakadeo	59.50	68.30
6	Tilaknagar	29.50	34.37
7	Oldkanpur	30.50	34.99
8	Sootergn	29.50	34.23
9	Khalasiline	26.50	30.85
10	Ashsokngr	20.50	23.41
11	Lagpatngr	34.50	39.64
12	Shastringr	34.50	39.57
13	Vijayangr	39.50	45.74
14	Darshanpur	33.50	38.83
15	Nehrunagar	30.50	35.54
16	Gandhingr	21.50	25.22
17	Rambag	24.50	28.34
18	Gwaltoli	35.50	40.78
19	Colonelgn	32.50	37.42
20	Bakergn	34.50	39.35
21	Chamangn	26.50	30.86
22	Sisamau	45.50	52.10
23	Civillines	42.50	48.45
24	Parade	34.50	39.44
25	Dalelpurwa	35.50	40.69
26	Raipurwa	25.50	30.07
27	Garibchoki	46.50	53.49

Table:10 Contd. on Page 59

Table:10 Contd from Page 58

Ward No	Ward Name	Population in Thousands	
		1991	1996
28	Gobindngr1	46.50	53.58
29	Gobindngr2	68.50	78.40
30	Juhi	190.50	217.75
31	Transptngr	39.50	45.66
32	Lakshmipur	38.50	44.57
33	Anwargn	27.50	32.26
34	Choksaraff	31.50	35.93
35	Chataimohalla	25.50	29.85
36	Patkapur	27.50	32.04
37	Generalgn	24.50	28.15
38	Motimahal	23.50	27.03
39	Munshipur	46.50	53.32
40	Ajitgn	33.50	38.65
41	Kidwaingr1	18.50	21.88
42	Kidwaingr2	36.50	42.26
43	Babupurwa	34.50	39.42
44	Sujalgn	40.50	47.19
45	Naubasta	72.50	83.54
46	Harbansmohal	22.50	26.28
47	Krinshangr	26.50	30.59
48	Harjinderngr	51.50	59.31
49	Jajamau	42.50	48.61
50	Chakeri	41.50	47.32
51	Rawatpurstn	3.50	4.14
52	Rlycolony	1.50	1.96

Table:11 Fuel Units and their Distribution

Ward No	Ward Name	Number of Fuel Units	% Users of stated Fuel Type				
			Cowdung	Wood	Koil	Coal	LPG
1	Kalyanpur	124715	0.0	3.0	43.0	17.0	37.0
2	Panki	184262	0.0	0.0	0.0	0.0	100.0
3	Rawatpur	15433	0.0	0.0	41.0	5.0	43.0
4	Nawabgn	11240	29.0	19.0	24.0	10.0	19.0
5	Kakadeo	13559	18.0	18.0	18.0	6.0	40.0
6	Tilaknagar	6773	0.0	0.0	40.0	40.0	20.0
7	Oldkanpur	6896	0.0	0.0	0.0	0.0	100.0
8	Sootergn	6745	22.0	22.0	34.0	22.0	0.0
9	Khalasiline	6070	17.0	13.0	30.0	35.0	5.0
10	Ashsokngr	4582	0.0	36.0	36.0	9.0	18.0
11	Lagpatngr	7827	12.0	25.0	31.0	6.0	25.0
12	Shastringr	7814	90.0	0.0	27.0	9.0	55.0
13	Vijayangr	9048	6.0	6.0	24.0	12.0	53.0
14	Darshanpur	7666	4.0	33.0	33.0	30.0	0.0
15	Nehrunagar	7008	12.0	25.0	33.0	19.0	12.0
16	Gandhinagar	4944	0.0	0.0	0.0	0.0	100.0
17	Rambag	5568	18.0	0.0	36.0	0.0	45.0
18	Gwaltoli	8055	0.0	0.0	0.0	0.0	100.0
19	Colonelgn	7384	0.0	8.0	42.0	17.0	33.0
20	Bakergn	7769	0.0	14.0	14.0	0.0	71.0
21	Chamangn	6071	9.0	17.0	30.0	9.0	35.0
22	Sisamau	10319	0.0	0.0	50.0	20.0	30.0
23	Civillines	9589	0.0	0.0	37.0	5.0	58.0
24	Parade	7788	0.0	0.0	0.0	0.0	100.0
25	Dalelpurwa	8038	0.0	31.0	46.0	0.0	23.0
26	Raipurwa	5914	0.0	29.0	43.0	29.0	0.0
27	Garibchoki	10597	0.0	0.0	25.0	0.0	75.0
28	Gobindngr1	10616	5.0	19.0	38.0	10.0	29.0
29	Gobindngr2	15579	0.0	0.0	50.0	0.0	50.0
30	Juhi	43449	0.0	0.0	60.0	0.0	40.0

Table:11 Contd. from Page 60

Ward No	Ward Name	Number of Fuel Units	% Users of stated Fuel Type				
			Cowdung	Wood	Koil	Coal	LPG
31	Transportnagar	9031	7.0	7.0	48.0	0.0	37.0
32	Lakshmipur	8813	7.0	29.0	29.0	29.0	7.0
33	Anwargn	6352	0.0	0.0	0.0	0.0	100.0
34	Choksaraff	7085	0.0	0.0	50.0	0.0	50.0
35	Chataimohalla	5870	0.0	0.0	50.0	0.0	50.0
36	Patkapur	6308	0.0	0.0	50.0	0.0	50.0
37	Generalgn	5530	0.0	0.0	33.0	34.0	33.0
38	Motimahal	5305	3.0	19.0	38.0	6.0	34.0
39	Munshipur	10564	0.0	17.0	33.0	0.0	50.0
40	Ajitgn	7630	20.0	0.0	40.0	20.0	20.0
41	Kidwaingr1	4276	0.0	0.0	0.0	0.0	100.0
42	Kidwaingr2	8351	0.0	5.0	25.0	5.0	65.0
43	Babupurwa	7783	0.0	0.0	0.0	0.0	100.0
44	Sujalgn	9337	12.0	12.0	38.0	6.0	31.0
45	Naubasta	16607	9.0	18.0	55.0	9.0	9.0
46	Harbansmohal	5156	0.0	0.0	33.0	34.0	33.0
47	Krishanagar	6018	0.0	0.0	0.0	0.0	100.0
48	Harjinderngr	11761	0.0	14.0	29.0	0.0	57.0
49	Jajamau	9622	0.0	55.0	0.0	9.0	36.0
50	Chakeri	9363	0.0	0.0	0.0	0.0	100.0
51	Rawatpurstn	728	0.0	0.0	0.0	0.0	100.0
52	Rlycolony	291	14.0	14.0	43.0	0.0	29.0

Table:12 Contd from Page 62

Ward No	Ward Name	Fuel Consumption per Fuel unit for Stated Fuel Type.				
		Cowdung kg/d	Wood kg/d	Koil L/d	Coal kg/d	LPG kg/d
26	Raipurwa	0.00	1.33	0.16	1.66	0.00
27	Garibchoki	0.00	0.00	0.16	0.00	0.47
28	Gobindnagar1	8.33	0.38	0.30	1.00	0.47
29	Gobindnagar2	0.00	0.00	0.33	0.00	0.47
30	Juhi	0.00	0.00	0.55	0.00	0.47
31	Transportngr	0.25	0.58	0.65	0.00	0.52
32	Lakshmipur	1.66	1.08	0.70	0.66	0.47
33	Anwargn	0.00	0.00	0.00	0.00	0.47
34	Choksaraff	0.00	0.00	0.16	0.00	0.47
35	Chataimohalla	0.00	0.00	0.27	0.00	0.47
36	Patakpur	0.00	0.00	0.16	0.00	0.47
37	Generalgn	0.00	0.00	0.66	0.85	0.47
38	Motimahal	0.16	0.33	0.44	0.74	0.47
39	Munshipur	0.00	0.33	0.33	0.00	0.63
40	Ajitgn	0.33	0.00	0.25	0.50	0.47
41	Kidwainagar1	0.00	0.00	0.00	0.00	0.47
42	Kidwainagar2	0.00	0.50	0.36	0.66	0.47
43	Babupurwa	0.00	0.00	0.00	0.00	0.47
44	Sujalgn	0.83	1.00	0.27	2.00	0.47
45	Naubasta	0.16	0.50	0.64	0.50	0.47
46	Harbansmohalla	0.00	0.00	0.58	0.66	0.47
47	Krishananagar	0.00	0.00	0.00	0.00	0.47
48	Harjindernagar	0.00	10.00	0.25	0.00	0.59
49	Jajmau	0.00	2.58	0.00	5.00	0.51
50	Chakeri	0.00	0.00	0.00	0.00	0.47
51	Rawatpurstn	0.00	0.00	0.00	0.00	0.47
52	Rlycolony	0.83	1.75	0.30	0.00	0.53

Table 13. Emission Factors for NO_x for Stated Fuel Type

Fuel	Emission factor kg/kg
Coal	0.02
Wood	0.007
Diesel	0.015
LPG	0.25
Kerosene oil	0.0025
Low diesel oil (LDO)	0.0075
Cowdung	0.007

Source: Central Pollution Control Board, Kanpur.

Table: 14 Warad Wise Average NOx Emission Rates Due to Domestic Sources.

Ward No	Ward Name	Emission Rate(kg/h) due to Stated Fuel For Domestic Use.					
		Cowdung	Wood	Koil	Coal	LPG	Total
1	Kalyanpur	0.00	0.22	0.72	3.12	520.63	524.70
2	Panki	0.00	0.00	0.00	0.00	902.12	902.12
3	Rawatpur	0.00	0.00	0.08	0.27	64.80	65.15
4	Nawabgn	0.28	0.13	0.02	0.26	39.87	40.57
5	Kakadeo	0.28	0.19	0.08	0.15	52.84	53.54
6	Tilakngr	0.00	0.00	0.02	0.54	24.14	24.71
7	Oldkanpur	0.00	0.00	0.00	0.00	33.77	33.77
8	Sootergn	0.05	0.12	0.04	0.14	0.00	0.35
9	Khalasi	0.04	0.08	0.01	0.81	20.12	21.06
10	Ashokngr	0.00	0.29	0.02	0.04	16.18	16.53
11	Lagpatngr	0.03	0.50	0.06	0.18	28.54	29.31
12	Shastringr	3.49	0.00	0.04	0.40	32.40	36.33
13	Vijaingr	0.36	0.02	0.04	0.16	37.21	37.79
14	Darshanpur	0.20	0.53	0.21	1.17	0.00	2.11
15	Nehrungr	0.47	0.30	0.03	0.65	30.69	32.15
16	Gandingr	0.00	0.00	0.00	0.00	24.20	24.20
17	Rambag	0.52	0.00	0.03	0.00	25.94	26.49
18	Gwaltoli	0.00	0.00	0.00	0.00	39.44	39.44
19	Colonelgn	0.00	0.08	0.05	0.26	26.73	27.12
20	Bakergn	0.00	0.29	0.01	0.00	48.14	48.43
21	Chamangn	0.13	0.23	0.07	1.00	35.48	36.90
22	Sisamau	0.00	0.00	0.05	0.97	38.50	39.52
23	Civilline	0.00	0.00	0.07	0.36	43.67	44.10
24	Prade	0.00	0.00	0.00	0.00	38.13	38.13
25	Dalelpurwa	0.00	0.51	0.03	0.00	29.05	29.59
26	Raipurwa	0.00	0.23	0.01	0.81	0.00	1.05
27	Garibchoki	0.00	0.00	0.02	0.00	47.47	47.49
28	Gobindngr1	0.44	0.08	0.04	0.30	39.43	40.29

Table:14 Contd.on Page 66

Table:14 Contd from Page 65

Ward No	Ward Name	Emission Rate(kg/h) due to Stated Fuel For Domestic Use.					
		Cowdung	Wood	Koil	Coal	LPG	Total
29	Gobindngr2	0.00	0.00	0.09	0.00	63.30	63.39
30	Juhi	0.00	0.00	0.51	0.00	169.32	169.83
31	Transportngr	0.02	0.04	0.10	0.00	38.44	38.59
32	Lakshmipur	0.10	0.27	0.06	0.48	29.50	30.42
33	Anwargn	0.00	0.00	0.00	0.00	31.10	31.10
34	Choksaraff	0.00	0.00	0.02	0.00	28.79	28.81
35	Chataimahal	0.00	0.00	0.03	0.00	23.85	23.88
36	Patakpur	0.00	0.00	0.02	0.00	25.63	25.65
37	Generalgn	0.00	0.00	0.04	0.45	20.90	21.40
38	Motimahal	0.00	0.03	0.03	0.07	20.14	20.27
39	Munshipur	0.00	0.06	0.04	0.00	57.54	57.64
40	Ajitgn	0.05	0.00	0.03	0.22	27.19	27.48
41	Kidwaingr1	0.00	0.00	0.00	0.00	20.93	20.93
42	Kidwaingr2	0.00	0.02	0.03	0.08	36.02	36.15
43	Babupurwa	0.00	0.00	0.00	0.00	38.11	38.11
44	Sujalgn	0.09	0.11	0.03	0.32	34.99	35.54
45	Naubasta	0.02	0.15	0.21	0.21	56.15	56.74
46	Harbansmohal	0.00	0.00	0.03	0.33	19.50	19.86
47	Krishnangr	0.00	0.00	0.00	0.00	29.46	29.46
48	Harjinderngr	0.00	1.63	0.03	0.00	61.71	63.37
49	Jajmau	0.00	1.35	0.00	1.23	40.00	42.58
50	Chakeri	0.00	0.00	0.00	0.00	45.84	45.84
51	Rawatpurstn	0.00	0.00	0.00	0.00	3.56	3.56
52	Rlycolony	0.00	0.01	0.00	0.00	1.22	1.23

Table:15 Ward Wise Peak NOx Emission Rates due to Domestic Sources.

Ward No	Ward Name	Emission Rates(kg/h) due to Stated Fuel for Domestic Use.					
		Cowdung	Wood	Koil	Coal	LPG	Total
1	Kalyanpur	0.00	1.34	4.33	18.74	2082.52	2106.93
2	Panki	0.00	0.00	0.00	0.00	3608.46	3608.46
3	Rawatpur	0.00	0.00	0.48	1.64	259.19	261.31
4	Nawabgn	1.71	0.79	0.13	1.59	159.49	163.69
5	Kakadeo	1.70	1.12	0.49	0.91	211.36	215.58
6	Tilakngr	0.00	0.00	0.14	3.27	96.57	99.98
7	Oldkanpur	0.00	0.00	0.00	0.00	135.07	135.07
8	Sootergn	0.29	0.73	0.23	0.83	0.00	2.09
9	Khalasiline	0.23	0.45	0.08	4.87	80.47	86.10
10	Ashokngr	0.00	1.76	0.12	0.23	64.70	66.81
11	Lagpatngr	0.18	3.00	0.38	1.06	114.17	118.80
12	Shastringr	20.92	0.00	0.25	2.39	129.60	153.16
13	Vijaingr	2.14	0.13	0.24	0.98	148.85	152.3
14	Darshanpur	1.21	3.18	1.25	7.00	0.00	12.63
15	Nehrungr	2.85	1.78	0.17	3.92	122.78	131.49
16	Gandhingr	0.00	0.00	0.00	0.00	96.82	96.82
17	Rambag	3.13	0.00	0.17	0.00	103.74	107.05
18	Gwaltoli	0.00	0.00	0.00	0.00	157.74	157.74
19	Colonelgn	0.00	0.47	0.28	1.58	106.93	109.26
20	Bakergn	0.00	1.72	0.04	0.00	192.56	194.31
21	Chamangn	0.78	1.39	0.39	5.97	141.90	150.44
22	Sisamau	0.00	0.00	0.31	5.83	153.98	160.12
23	Civilline	0.00	0.00	0.39	2.17	174.68	177.23
24	Parade	0.00	0.00	0.00	0.00	152.51	152.51
25	Dalelpurwa	0.00	3.08	0.17	0.00	116.21	119.46
26	Raipurwa	0.00	1.36	0.09	4.84	0.00	6.28
27	Garibchoki	0.00	0.00	0.09	0.00	189.88	189.97
28	Gobindngr1	2.62	0.46	0.26	1.80	157.72	162.87
29	Gobindngr2	0.00	0.00	0.55	0.00	253.21	253.76
30	Juhi	0.00	0.00	3.05	0.00	677.29	680.34

Table: 15 Contd from Page 67

Ward No	Ward Name	Emission Rates(kg/h) due to Stated Fuel for Domestic Use.					
		Cowdung	Wood	Koil	Coal	LPG	Total
31	Tranportngr	0.09	0.22	0.60	0.00	153.75	154.66
32	Lakshmipur	0.61	1.64	0.38	2.87	118.01	123.51
33	Anwargn	0.00	0.00	0.00	0.00	124.39	124.39
34	Choksaraff	0.00	0.00	0.12	0.00	115.15	115.27
35	Chataimahal	0.00	0.00	0.17	0.00	95.41	95.58
36	Patakpur	0.00	0.00	0.11	0.00	102.52	102.63
37	Generalgn	0.00	0.00	0.26	2.72	83.60	86.57
38	Motimahal	0.02	0.20	0.19	0.40	80.57	81.37
39	Munshipur	0.00	0.35	0.24	0.00	230.16	230.76
40	Ajitgn	0.30	0.00	0.16	1.30	108.77	110.53
41	Kidwaingr1	0.00	0.00	0.00	0.00	83.74	83.74
42	Kidwaingr2	0.00	0.12	0.16	0.47	144.09	144.85
43	Babupurwa	0.00	0.00	0.00	0.00	152.44	152.44
44	Sujalgn	0.55	0.67	0.20	1.90	139.94	143.27
45	Naubasta	0.14	0.89	1.24	1.27	224.58	228.13
46	Harbansmahal	0.00	0.00	0.21	1.97	77.98	80.16
47	Krishanangr	0.00	0.00	0.00	0.00	117.83	117.83
48	Harjinderngr	0.00	9.80	0.18	0.00	246.84	256.
49	Jajmau	0.00	8.12	0.00	7.35	159.99	175.46
50	Chakeri	0.00	0.00	0.00	0.00	183.38	183.38
51	Rawatpurstn	0.00	0.00	0.00	0.00	14.26	14.26
52	Rlycolony	0.02	0.04	0.01	0.00	4.88	4.95

4.7 STEPS TO COMPUTE AVERAGE, NO_x EMISSION RATES, AREA WISE, DUE TO POINT SOURCES

(i) Area wise data is collected for average, daily fuel consumption rates, of various fuel types by the industries. The data of average, daily, fuel consumption rates for the various fuel types e.g. low diesel oil, coal, wood and diesel are given in Table 16. This data is given for various industries located in different areas.

(ii) Area wise, average, daily fuel consumption rates are computed for all the fuel types for all the industries, located area wise. Emission rates are computed area wise for NO_x for all the fuel types. These emission rates are summed up to give the total average emission rate for NO_x area wise.

Table: 16 Estimated Average Industrial Fuel Consumption Rates.

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
1	Jajmau	Ig_shoes	0.00	4.00	0.00	0.00
2	Panki	Sumak_power	0.00	0.00	0.00	10.00
3	Panki	Jagmohan_auto	0.00	0.00	0.00	20.00
4	Panki	LML_scooter	3000.00	0.00	0.00	0.00
5	Panki	Munna_indus	0.00	0.00	0.00	30.00
6	Panki	Neelkanth	4000.00	0.00	0.00	0.00
7	Panki	Fairform	0.00	5.00	0.00	0.00
8	Fazalgn	Treads_India	0.00	0.00	0.00	40.00
9	Dadangr	Tinwin	0.00	0.00	0.00	1.50
10	Dadangr	Timrubber	0.00	6.00	0.00	40.00
11	Dadangr	Universal	0.00	0.00	0.00	20.00
12	Govindngr	Umafood	15000.00	0.00	0.00	0.00
13	Dadangr	Vishu_indus	0.00	0.00	0.00	100.00
14	Kalpiroad	Ordfactory	720.00	4.80	0.00	0.00
15	Panki	Sumit_indus	0.00	4.80	0.00	0.00
16	Ghatampur	Ms_indus	0.00	6000.00	0.00	0.00
17	Ghatampur	Vikram_indus	0.00	10000.00	0.00	0.00
18	Rania	Banarsidas	0.00	20000.00	0.00	400.00
19	Dadangr	Avondying	0.00	0.20	0.00	0.00
20	Rania	Atul_refiners	0.00	100.00	0.00	1500.00
21	Sarvoday	Asha_indus	0.00	10.00	0.00	100.00
22	Sareshbag	Mk_indus	0.00	0.00	0.00	20.00
23	Rania	Rajendra	100.00	0.00	0.00	6400.00
24	Rania	Rajendrasteel	0.00	0.00	0.00	30.00
25	Bhoganipur	Agarwal	0.00	0.00	0.00	20.00
26	Dadangr	Ashoka	0.00	8.00	0.00	0.00
27	Panki	Threadus	0.00	0.00	0.00	2000.00
28	Fazalgn	Indiacoating	0.00	0.00	0.00	100.00
29	Fazalgn	Associated	0.00	0.20	0.00	0.00
30	Jazmau	Supertennery	0.00	500.00	0.00	0.00

Table 16 Contd. from Page 70

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
31	Indusarea	Motilal	0.00	0.00	0.00	30.00
32	Jajmau	Northtennry	0.00	0.50	0.00	0.00
33	Dadanagr	Sparkfiber	0.00	0.00	0.00	400.00
34	Dadanagr	Asiapen	0.00	0.00	0.00	10.00
35	Bhawanipur	Primier	0.00	0.10	0.00	0.00
36	Dadanagr	Gopal	200.00	0.00	0.00	10.00
37	Jainpur	Pioneer	0.00	1.00	0.00	0.00
38	Panki	Ms-silica	0.00	21.50	0.00	0.00
39	Rawatpr	Up_leminator	0.00	10.00	0.00	0.00
40	Jainpur	Sevan	0.00	0.30	0.00	0.00
41	Jajmau	Indianms	0.00	0.20	1000.00	0.00
42	Panki	Frontier	0.00	0.00	0.00	4.00
43	Fazalgn	Bangal	0.00	0.15	0.00	0.00
44	Jazmau	Superhouse	0.00	0.00	0.00	360.00
45	Panki	Thermalpower	69890.00	3926620.00	0.00	0.00
46	Civilline	Woolenmill	0.00	30.00	0.00	0.00
47	Panki	Sarswati	0.00	0.00	0.00	100.00
48	Jazmau	Asian	0.00	0.10	1500.00	50.00
49	Fazalgn	Aliya	0.00	2000.00	0.00	30.00
50	Panki	Ratopumps	0.00	10.00	0.00	50.00
51	Panki	LML	1200.00	0.00	0.00	350.00
52	Panki	Phonex	0.00	0.00	0.00	100.00
53	Sareshbag	Jyoti	0.00	0.00	0.00	30.00
54	Anwargn	Earthen	0.00	130000.00	0.00	0.00
55	Indusstate	Stdoil	0.00	30000.00	0.00	0.00
56	Panki	Kiran	0.00	150.00	0.00	0.00
57	Fazalgn	Komal	0.00	0.00	0.00	100.00
58	Dadangr	Jetational	0.00	0.00	0.00	100.00
59	Indusstate	Sarasoaps	100.00	0.00	0.00	0.00
60	Indusstate	Textileltd	0.00	10.00	0.00	0.00
61	Dadangr	Kirpaltextl	0.00	0.00	0.00	200.00

Table 16 Contd. on Page 72

Table 16 Contd. from Page 71

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
62	Panki	Kehar	0.00	0.00	0.00	3000.00
63	Sareshbag	Kamlesh	0.00	1000.00	0.00	0.00
64	Jazmau	Kentech	0.00	10.00	0.00	0.00
65	Indusstate	Swati	500.00	0.00	0.00	0.00
66	Indusstate	Ramshyam	0.00	0.00	52.00	0.00
67	Indusstate	Ramdas	0.00	1000.00	0.00	0.00
68	Indusstate	Kishan	0.00	0.00	0.00	40.00
69	Civillines	Riversite	0.00	200000.00	0.00	0.00
70	Indusstate	Motilal	0.00	1800.00	0.00	0.00
71	Panki	Garg	0.00	0.00	0.00	300.00
72	Indusstate	Games	0.00	0.00	0.00	20.00
73	Panki	Vishwakarma	0.00	0.25	0.00	0.00
74	Indusstate	Sharad	0.00	0.00	0.00	200.00
75	Indusstate	Siddarth	0.00	1.50	0.00	2000.00
76	Indusstate	Smtraders	0.00	0.00	0.00	500.00
77	Indusstate	Singh	0.00	2.00	0.00	0.00
78	Indusstate	Stdtin	2000.00	0.00	0.00	0.00
79	Indusstate	Bansal	0.00	0.00	0.00	2000.00
80	Indusstate	Virazu	0.00	100.00	0.00	0.00
81	Dadangr	Yadav	0.00	3000.00	0.00	0.00
82	Fazalgn	Vijay	0.00	400.00	0.00	0.00
83	Panki	Shivam	0.00	0.00	0.00	60.00
85	Panki	Jakhodita	0.00	40000.00	0.00	0.00
86	Panki	Indochem	0.00	0.18	0.00	0.00
87	Indusstate	Muirmill	0.00	22.00	0.00	0.00
88	Panki	Mineraloil	100.00	0.00	0.00	0.00
89	Indusstate	Navrang	0.00	0.10	0.00	0.00
90	Panki	Mahendra	0.00	0.00	100.00	0.00
91	Indusstate	Malik	0.00	1.00	0.00	0.00
92	Panki	Mitu	0.00	0.00	0.00	300.00
93	Panki	Pahaldari	0.00	2.50	0.00	0.00

Table 16 Contd. on Page 73

Table 16 Contd. from Page 72

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
94	Indusstate	Peacock	0.00	0.00	0.00	200.00
95	Panki	Polymer	0.00	25.00	0.00	150.00
96	Dadangr	Newheer	0.00	0.00	0.00	200.00
97	Indusstate	Pashupati	0.00	0.00	0.00	200.00
98	Fazalgn	Neha	0.00	0.00	0.00	60.00
99	Indusstate	Pratap	0.00	300.00	0.00	0.00
100	Juhi	Prahalad	0.00	100.00	0.00	500.00
101	Panki	Prakarti	0.00	100.00	0.00	0.00
102	Indusstate	Pradeep	0.00	2.50	0.00	0.00
103	Panki	Synthetic	0.00	0.00	0.00	200.00
104	Panki	Gugrat	0.00	12.50	0.00	0.00
105	Dadanagr	Jaidurga	0.00	7.50	300.00	0.00
106	Fazalgn	Gurdhar	0.00	400.00	0.00	0.00
107	Panki	Singhwks	0.00	5000.00	0.00	0.00
108	Panki	Autoindia	0.00	0.00	0.00	250.00
109	Indusstate	Ashis	0.00	0.12	0.00	0.00
110	Indusstate	Jokhodia	0.00	0.00	0.00	2000.00
111	Dadanagr	Annucut	0.00	0.00	0.00	360.00
112	Panki	Rajkamal	0.00	0.00	0.00	40.00
113	Dadanagr	Rirubber	0.00	0.50	0.00	0.00
114	Panki	Lohia	0.00	0.00	0.00	480.00
115	Panki	Latex	0.00	150.00	0.00	0.00
116	Fazalgn	Chromium	0.00	0.00	0.00	200.00
117	Indusstate	Hycoplast	0.00	0.00	0.00	288.00
118	Dadangr	Garg	0.00	1000.00	0.00	0.00
119	Dadangr	Ragshree	0.00	0.00	40.00	0.00
120	Fazalgn	Royalcold	11500.00	0.00	0.00	0.00
121	Dadangr	Rehanfood	0.00	0.00	0.00	200.00
122	Panki	Rohitoil	0.00	4000.00	0.00	0.00
123	Dadangr	Rbfood	0.00	0.00	0.00	40.00
124	Indusstate	Raliable	0.00	21.60	0.00	0.00

Table 16 Contd. on Page 74

Table 16 Contd. from Page 73

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
125	Panki	Raju	0.00	1500.00	10.00	0.00
126	Panki	Rlchemical	0.00	0.80	0.00	200.00
127	Dadangr	Prakash	0.00	0.12	0.00	0.00
128	Indusstate	Ajit	0.00	0.00	0.00	20.00
129	Panki	Dinesh	0.00	0.00	0.00	50.00
130	Indusstate	Devicharan	0.00	3.00	0.00	0.00
131	Indusstate	Bonded	0.00	2000.00	0.00	0.00
132	Indusstate	Bajrang	400.00	0.00	0.00	30.00
133	Dadangr	Ashok	0.00	0.00	0.00	200.00
134	Indusstate	Bharat	20.00	0.00	0.00	200.00
135	Panki	Crystal	0.00	0.50	0.00	0.00
136	Indusstate	Gopi	5.00	0.20	0.00	0.00
137	Panki	Hindchemical	0.00	0.40	0.00	80.00
138	Fazalgn	Girdhar	0.00	0.00	0.00	200.00
139	Indusstate	Ciniken	0.00	0.00	0.00	15.00
140	Sareshbag	Classic	0.00	0.00	0.00	20.00
141	Dadangr	Frontier	0.00	0.00	0.00	200.00
142	Panki	Essarelect	0.00	0.00	0.00	20.00
143	Panki	Sharpengg	0.00	0.00	0.00	50.00
144	Panki	Geoken	0.00	0.00	0.00	50.00
145	Indusstate	Thredindia	1691.00	0.00	0.00	0.00
146	Panki	Gschemical	0.00	0.00	15000.00	0.00
147	Indusstate	Jaisteel	800.00	0.00	0.00	0.00
148	Indusstate	Skbluchers	0.00	0.60	0.00	0.00
149	Indusstate	Kishan	0.00	0.60	0.00	0.00
150	Kalpird	Smallarms	0.00	0.00	0.00	200.00
151	Panki	Indoil	0.00	0.00	0.00	240.00
152	Jazmau	Gargchem	8.00	0.00	0.00	250.00
153	Indusstate	JK_jute	0.00	0.21	0.00	0.00
154	Panki	Knchem	0.00	2150.00	0.00	0.00
155	Panki	Knrubber	0.00	2150.00	0.00	0.00

Table 16 Contd. on Page 75

Table 16 Contd. from Page 74

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
156	Indusstate	Dugadhi	0.00	0.00	0.00	2000.00
157	Jazmau	Sultan	0.00	0.50	0.00	0.00
158	Jazmau	Newlight	0.00	0.50	1000.00	0.00
159	Jazmau	Sunrise	0.00	1.00	0.00	4800.00
160	Jazmau	Upperindia	0.00	0.50	0.00	5000.00
161	Jazmau	Untdprovince	0.00	1.00	0.00	0.00
162	Indusstate	Vivek	0.00	0.00	0.00	225.00
163	Panki	Rastogi	0.00	0.40	0.00	0.00
164	Indusstate	Summet	0.00	2.00	0.00	0.00
165	Panki	Takebright	0.00	0.00	0.00	64.00
166	Panki	Sarvoday	0.00	0.15	0.00	0.00
167	Panki	Vimal	0.00	0.15	10.00	0.00
168	Jazmau	Zaztannery	0.00	0.00	0.00	500.00
169	Indusstate	Shbihari	0.00	0.00	0.00	384.00
170	Panki	Shivshakti	0.00	0.12	0.00	0.00
171	Indusstate	Jagdish	0.00	0.00	0.00	2000.00
172	Panki	Kapoor	0.00	0.00	0.00	84.00
173	Indusstate	Jkzink	0.00	0.00	0.00	10.00
174	Panki	LMLfiber	0.00	18.00	0.00	0.00
175	Panki	Agarwal	0.00	0.00	0.00	200.00
176	Panki	Knplastic	0.00	0.00	0.00	2000.00
177	Panki	Hyberchem	0.00	0.00	0.00	300.00
178	Indusstate	Kurela	0.00	0.00	0.00	50.00
179	Panki	Hindustan	0.00	2000.00	0.00	0.00
180	Jazmau	Sunshine	0.00	0.10	0.00	0.00
181	Indusstate	Bchem	0.00	1000.00	0.00	0.00
182	Fazalgn	Bharat	350.00	0.00	0.00	0.00
183	Indusstate	Ganga	0.00	0.40	0.00	2000.00
184	Indusstate	Kncigreete	0.00	0.00	0.00	105.00
185	Panki	Esslon	0.00	16.00	0.00	0.00
186	Indusstate	Kdrubber	0.00	0.25	0.00	0.00

Table 16 Contd. on Page 76

Table 16 Contd. from Page 75

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
187	Industate	Khan	500.00	0.00	0.00	300.00
188	Industate	Khurana	0.00	1100.00	0.00	0.00
189	Industate	Blagarwal	750.00	0.00	0.00	0.00
190	Industate	Udyogsamiti	0.00	0.00	0.00	100.00
191	Industate	National	0.00	2000.00	0.00	0.00
192	Industate	Satulaj	0.00	0.00	0.00	32.00
193	Industate	Kckapoor	0.00	0.00	0.00	15.00
194	Industate	Modernfood	0.00	0.00	0.00	2000.00
195	Panki	Rubberage	0.00	0.15	0.00	0.00
196	Fazalgn	Nagratt	0.00	0.00	0.00	20.00
197	Panki	Saha	0.00	0.00	0.00	500.00
198	Industate	Jaiswal	0.00	800.00	0.00	0.00
199	Industate	Jyoti	0.00	300.00	0.00	0.00
200	Industate	Modern	0.00	0.20	0.00	30.00
201	Industate	Redron	700.00	0.00	0.00	0.00
202	Industate	Shram	0.00	3.00	0.00	0.00
203	Industate	Tmsoaps	0.00	0.00	600.00	100.00
204	Industate	Vindrakan	0.00	0.00	0.00	50.00
205	Industate	Semkt	0.00	0.00	0.00	350.00
206	Panki	Sngtraders	0.00	10.00	0.00	0.00
207	Industate	Unvprogress	0.00	0.00	0.00	20.00
208	Panki	Ssindustries	0.00	0.15	0.00	5.00
209	Industate	Unique	0.00	0.00	50000.00	0.00
210	Industate	National	0.00	1500.00	0.00	0.00
211	Industate	Virendravan	300.00	0.00	0.00	0.00
212	Industate	Triveni	0.00	0.10	0.00	0.00
213	Panki	Zincindia	0.00	0.60	0.00	0.00
214	Industate	Vikas	0.00	0.10	0.00	0.00
215	Industate	Tgtraders	0.00	0.00	0.00	20.00
216	Industate	Superrubber	0.00	0.00	0.00	100.00
217	Industate	Idealchem	0.00	0.00	0.00	100.00

Table 16 Contd. on Page 77

S. No.	Location	Name of Industry	Fuel Consumption Per Industry for Stated Fuel Type			
			Ldo l/d	Coal t/d	Wood kg/d	Diesel l/d
218	Indusstate	Kothari	0.00	0.00	0.00	100.00
219	Indusstate	Ess	0.00	0.00	0.00	4.00
220	Indusstate	JKcotton	0.00	27300.00	0.00	463.00
221	Indusstate	Metal	0.00	0.10	0.00	0.00
222	Indusstate	Malayagiri	0.00	2.50	0.00	0.00
223	Panki	Mechoil	0.00	0.00	0.00	200.00
224	Dadangr	Nitin	0.00	0.40	0.00	0.00
225	Fazalgn	Mahavir	0.00	25.00	0.00	0.00
226	Indusstate	Madhur	0.00	0.00	0.00	20.00
227	Indusstate	Prakati	0.00	0.00	0.00	7200.00
228	Indusstate	Newson	0.00	0.00	200.00	0.00
229	Indusstate	Patlu	0.00	0.15	0.00	0.00
230	Indusstate	Peacock	0.00	4500.00	0.00	0.00
231	Indusstate	Pilcofarma	0.00	0.00	0.00	200.00
232	Indusstate	Prestigepaint	0.00	0.00	0.00	20.00
233	Indusstate	Universal	0.00	0.00	0.00	100.00
234	Indusstate	Sunder	0.00	0.20	0.00	0.00
235	Panki	Singhania	0.00	5000.00	0.00	0.00
236	Dadangr	Indus_elc	0.00	0.00	0.00	50.00
237	Indusstate	Int_silica	0.00	2000.00	0.00	0.00
238	Panki	LMLltd	1440.00	0.00	0.00	0.00
239	Indusstate	Anupam	0.00	0.25	0.00	0.00
240	Indusstate	Sunderson	0.00	5000.00	0.00	0.00
241	Indusstate	Gulathi	0.00	0.00	0.00	50.00
242	Indusstate	Laxmi	270.00	0.00	0.00	0.00
243	Indusstate	Autoengg	250.00	0.00	0.00	0.00
244	Indusstate	Atul	0.00	0.25	0.00	0.00
245	Indusstate	Lohia	0.00	0.00	0.00	15.00
246	Indusstate	Lunarchem	0.00	2300.00	0.00	0.00
247	Panki	Lohia	0.00	0.00	0.00	13.00
248	Dadangr	Leoauto	0.00	0.00	0.00	30.00

Table 17 Area Wise Average NOx emission Rates Due to Point Sources.

Ward No	Ward Name	Emission Rate (kg/h) due to Point Sources.
1	Jagmau	23.19
2	Panki	3324211.1
3	Industrialstate	73221.72
4	Dadanagar	3350.66
5	Govindnagar	4.69
6	Ghatampur	13333.33
7	Rania	16755.24
8	Sarvodaynagar	8.40
9	Sareshbag	833.36
10	Bhoganipur	0.09
11	Juhi	83.65
12	Anwargang	108333.34
13	Civilline	166691.67
14	Jainpur	1.08
15	Rawatpur	1.01

Table 18. Average Annual NO_x Emissions Due to Line Sosurce, Area Source and Point Source for the Whole Kanpur City

Sl. No.	Emission rate (t) for the source stated type			
	Line source	Area source	Point source	Total
1.	$7.82 * 10^3$	$2.79 * 10^7$	$3.2494 * 10^7$	$6.04 * 10^7$

Table 19. Annual CO Emissions Due to Line Source for the Whole Kanpur City

Sl. No.	Emission rate (t) for the traffic condition stated type	
	Peak traffic volume	Average traffic volume
1.	$4.54234 * 10^5$	$5.768 * 10^4$

Table 20. Annual NO_x Emissions Due to Area Source for the Whole Kanpur City

Sl. No.	Emission rate (t) for the condition stated type	
	Peak	Average
1.	$11.197 * 10^4$	$2.79 * 10^4$

5. RESULTS AND DISCUSSION

5.1

Emission inventory is being prepared for Kanpur city due to line source, area source and point source. Results are presented and discussed in the following manner:

(i) Fig. 10 shows the contour map of Kanpur city showing all the road network, wards and industrial area. A railway track is being shown running along the N-W and S-E direction. All the major roads of the city are numbered from 1 to 63. All the wards are numbered from 1 to 52. Wards are shown with the boundaries with the ward number marked inside. Industrial areas are represented with the boundaries with the sign of an industry marked inside and the name of the area written adjacent to it. Ganges river is shown flowing N-W to E-S.

Kanpur is one of the eight industrial centre of India with an estimated population of around 21 lakhs. It has around 7000 industries both big and small. It has around 33277 LTV, 15161 HDV, 248 MDV and 2.5 lakhs TW.

(ii) Table 1 gives the road number, road name and PCU (number/h) for all the major road network of Kanpur city. It also gives the traffic volumes for TWV, LTV and HTV for average and peak traffic conditions. Fig. 1 shows the increase in vehicles over last five years for TWV, LTV and HTV. It is obvious from Fig. 1 that increase in vehicle number of all types over past five years is a linear one.

Hence, arithmetic mean method is used to predict the traffic volumes of all vehicle types for the year 1996. Table 2 shows the equations representing the relationship between the number of vehicles and year for TWV, LTV and HTV. It also gives the multiplication factors for the predicted year 1996 for TWV, LTV and HTV.

(iii) Table 3 shows the equations representing relationship between speed of a vehicle and the total traffic volume. These equations are used to compute speed of a vehicle of all types and the speed is a function of total traffic volume. These equations are applicable for all the urban Indian cities situated on the plain terrain. Since, emission factor is a direct function of speed, hence from the total traffic volumes the speed of all vehicle types are computed conveniently and are later used to compute emission factors for different types of vehicles. Table 4 shows the equations representing relationship between speed of a vehicle and the emission factor for NO_x and CO. Fig. 2 and Fig. 3 show the change in emission factor with the change in speed for NO_x and CO respectively. It is obvious from Fig. 2 and Fig. 3 that HTV produce more NO_x emissions than LTV and TWV. While LTV and TWV produce more CO emissions than HTV. This is also confirmed from Tables 5, 6, 7 and S respectively. Tables 5 and 6 show emissions during average and peak traffic conditions for NO_x while Tables 7 and 8 show emissions during average and peak traffic conditions for CO.

(iv) Fig. 4 shows the legend details. Symbols shown in Fig. 4 represent the emissions written in front of them. Fig. 6 shows the average NO_x emissions on different road network during average traffic conditions. Symbols representing the emissions are shown all along the road itself. They represent the emissions in kg/h/km on the road where they are marked. These emissions are also given in Table 5. Table 5 also gives the road number and road name. Fig. 10 is compared with Fig. 6 to find out the road number and from Table 5 road name is identified. In Fig. 6 average NO_x emissions are shown for each ward due to area source and also for each industrial area due to point source. Fig. 10 is marked to find out the ward number and industrial area. Table 14 and Table 17 give the average NO_x emissions due to area source and point source respectively. These table also give the names of the wards and industrial areas. Symbols representing the emissions are marked inside the boundaries of the wards and industrial areas in Fig. 6.

Similarly Fig. 5 shows the NO_x emissions on different road network during peak traffic condition. Figs. 7 and 8 show the CO emissions on different road network during average and peak traffic conditions respectively.

(v) Increase in population number over the years is shown in Fig. 9. It is obvious from Fig. 9 that there is a linear increase in population number over the past 10 years for HIG, MIG and LIG. Hence, the population for high income

group (HIG), middle income group (MIG) and low income group (LIG) is predicted for the year 1996 using arithmetic mean method. Ward wise estimated population for 1991 and 1996 is given in Table 10.

(vi) Ward wise NO_x emission rates due to area source are given in Tables 14 and 15 for average and peak conditions respectively. It is obvious that peak NO_x emissions are four times greater than the average NO_x emissions. It is assumed that a fuel unit burns for 6 h a day and this is also being confirmed by the socio-economic survey data. Table 20 gives the annual NO_x emissions due to area source for the city. Area wise average NO_x emission rates due to point source are given in Table 17. Table 18 gives the average annual NO_x emissions due to line source, area source and point source. Table 19 gives the average and peak annual NO_x emissions for CO due to line source. Emissions due to line source and area source are released to the atmosphere as there is no control to check the emissions by the users. Emissions due to point source are generated but not released to the atmosphere as there is a control measure applied by the industry. As per the information given by the Central Pollution Control Board, Kanpur there is no industry releasing NO_x to the atmosphere.

6. CONCLUSIONS

Following conclusions are drawn from this study:

(i) Maximum NO_x emissions (129.20 kg/h/km) remains during peak traffic hour on Juhi Junction-Afimkothi road. Minimum NO_x emissions (2.84 kg/h/km) remains on Jajmau-Bypass road during average traffic hour. Maximum CO emissions during peak traffic hour on Juhi Junction-Afimkothi road is 5714.88 kg/h/km. Minimum CO emissions during average traffic hour on Jajmau-Bypass road is 6.33 kg/h/km.

(ii) Total annual average and peak emissions for NO_x due to line source for the Kanpur city are $7.829 * 10^3$ ton and $16.61 * 10^3$ ton respectively. Total annual average and peak emissions for CO due to line source for the Kanpur city are $5.768 * 10^4$ ton and $4.5423 * 10^5$ ton respectively.

(iii) Maximum emissions due to area source is because of extensive use of LPG. LPG remains the prime source of domestic fuel for HIG and MIG people while 5 to 30 percent LIG people also use LPG.

(iv) Maximum NO_x emission due to area source during peak hour is 3608.46 kg/h in Panki location. Minimum NO_x emission due to area source during average hour is 0.35 kg/h in Sooterganj location. Total annual average NO_x emission due to area source in Kanpur city is $2.79 * 10^4$ ton. Total annual peak NO_x emission due to area source in Kanpur city is $11.195 * 10^4$ ton.

(v) Total annual average NO_x emission due to point source in Kanpur city is $3.2494 * 10^7$ ton. This emission is not released to the atmosphere.

(vi) Total annual average NO_x emission due to line source area source and point source in Kanpur city is $3.25297 * 10^7$ ton.

These emissions as mentioned above have been computed based on certain assumptions.Hence,before arriving at a final decision,these have to be verified by ground measurements. In the computation of line source emission,it has been assumed that traffic volume remains same through out the length of the road which has to be verified by conducting traffic survey all along the length of the road. In the computation of area source emission the survey which was done to find out the fuel consumption pattern for different wards might not represent the actual fuel consumption pattern as the survey was confined for 20 houses only in each ward.In order to find out the actual fuel consumption pattern, survey has to be conducted for large number of houses in each ward. In the computation of point source emission,it has been assumed that the fuel consumption rate remains constant which has to be verified from the industries.Percentage control actually applied by the industries also has to be verified. After verification this emission inventory can be used as an input for predictig air quality for Kanpur city.

REFERENCES

1. Inman, R. (1971). "Note on Uptake of CO by Soil Fungi", JAPCA, 21, No. 10, 646.

2. EPA (1975). "Compilation of Air Pollutant Emission Factors", USA.

3. EPA (1978). "Mobile Sources Emission Factors", Report No. 400/9-78-006, USA.

4. EPA (1980). "Mobile Emission Factors", Office of Transportation and Land Use Policy, USA.

5. Pierson, W.W. (1978). "Sulfate Emission from Vehicles on the Road", JAPCA 28: 123.

6. Chang, J.M. (1979). "Revised Weighting of CVS/CH Taft Results for CO Vehicle Emission Factors", JAPCA 28: 700.

7. Dignon, S.K. (1989). "Global Emissions of Nitrogen and Sulfur Oxides from 1860 to 1980", JAPCA 39: 180-186.

8. Blumenthal, D. and Roberts, J.G. (1987). "Southern California Air Quality Study (SCAPS) Program Plan", Final report to the California Air Resources Board.

9. Seinfield, J. (1986). "Analysis of the Southern California Air Quality Study Measurement Plan", SCAQS Model Working Group, Final report to the Coordinating Research Council.

10. Mirubella, M. (1989). "Development of the SCAQS Emission Inventory: An Overview", A & WMA Paper 111.4.

11. Yotter, D.L. (1989). "Development of a Grided Motor Vehicle Emission Inventory for the SCAQS", A & WMA Paper 137.2.

12. Chang, J.M. (1980). "Urban Centre CO Air Quality Projections", JAPCA 30: 1022.

13. Highway Research Record (1969). "Bibliography on Air Pollution", No. 278, pp. 12-14, USA.

14. Gschwandter, K.E. (1986). "Histotic Emissions of Sulfur and Nitrogen Oxides from 1900 to 1980", JAPCA 36: 139.

15. Nationwide Inventory of Air Pollutant Emissions (1968). U.S. Public Health Service, Dept. of Health Education and Welfare, Washington, D.C., 1970.

16. EPA (1978). National Air Pollutant Emissions Estimates (1970-1976), 450/1-78-003, USA.

17. EPA (1987). National Air Pollutant Emissions Estimates (1940-1985), 450/4-86-018, Research Triangle Park, NC, USA.

18. Khudson, D.A. (1986). "Estimated Monthly Emissions of Sulphur Dioxide and Oxides of Nitrogen for the 48 Contiguous States (1975-1984), ANL/EES-TM-318, Argonne National Laboratory, Chicago, IL, USA.

19. Dignon, S.H. (1985). "A Model Investigation of the Impact of Increases in Anthropogenic NO_x Emissions between 1967 and 1980 on Tropospheric Zone", Journ. of Atmos. Chem. 3: 491.

20. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part II - Delhi", CUPS/18, New Delhi.

21. Bandyopadhya, A.S.N. (1979). "Automobile Air Pollution and Its Control", Indian HIghways, Indian Road Congress, pp. 32-38.

22. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part IV - Calcutta", CUPS/20.

23. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part V - Bangalore", CUPS/21.

24. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part VI - Madras", CUPS/23.

25. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part VIII - Pune", CUPS/23.

26. CPCB (1988-89). "Assessment of Vehicular Pollution in Metropolitan Cities, Part VIII - Hyderabad", CUPS/24.